Recent productivity developments and technical change in Danish organic farming - stagnation?

Sauer, Johannes; Graversen, Jesper Tranbjerg; Park, Tim; Rasmussen, Solange Lohmann; Tvedegaard, Niels

Publication date:
2006

Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Sauer, J., Graversen, J. T., Park, T., Rasmussen, S. L., & Tvedegaard, N. (2006). *Recent productivity developments and technical change in Danish organic farming - stagnation?* Center for Skov, Landskab og Planlægning/Københavns Universitet. IFRO Working Paper Vol. 2006 No. 8

Recent Productivity Developments and Technical Change in Danish Organic Farming – Stagnation?

Johannes Sauer, Jesper Graversen, Tim Park, Solange Sotelo, Niels Tvedegaard

E-mail js@foi.dk

Abstract

This paper attempts to quantitatively measure the change in the productivity of Danish organic farming in recent years by using panel data on 56 organic farms mainly engaged in milk production for the period 2002 to 2004. Based on a translog production frontier framework the technical and scale efficiency on farm level is analysed by considering also curvature consistency. The total change in productivity for the reference period is measured by using the Malmquist total factor productivity index approach based on a time trends as well as a general index model specification. Input specific bias in technical change as well elasticities of input substitution are analyzed. Fators for the development of technical change and the change in efficiency over time are investigated by applying a bootstrapped ITSUR technique. Finally we try to conclude on the significance of subsidies for promoting long term growth in organic production by estimating a bootstrapped bivariate probit model with respect to factors influencing the probability of organic market exit. The results revealed significant differencies in the organic farms' technical efficiencies, no significant total factor productivity growth and even a slightly negative rate of technical change in the period investigated. These empirical results seem not strong enough to support the view of a profound stagnation in organic milk farming over the last years. We found evidence for a positive relationship between subsidy payments and an increase in farm efficiency, technology improvements and a decreasing probability of organic market exit which was also confirmed for off farm income. Finally the general index model specification was found to deliver a more accurate mapping of total factor productivity growth.

Contents

Preface

This research work has been done by assistant professor Johannes Sauer in collaboration with research assistant Jesper Graversen, fuldmægtig Niels Tvedegaard, fuldmægtig Solange Sotelo, as well as associate professor Tim Park, University of Georgia/USA.

Research director Mogens Lund has reviewed the paper and secretary Inger Sommer edited the final version.

Institute for Food and Resource Economics
Production and Technology Division, August 2006

Mogens Lund

1. Introduction

The promotion of organic farming has become an essential element of supranational and national food policy throughout Europe as well as other continents to promote safe and environmentally friendly food production. The characteristics of organic technology and the rules regulating its application are well defined and standardised for crop as well as livestock farming. However, the finding that organic farming technology has developed with relatively little input from scientific oriented research still holds (see Oude Lansink et al. 2002). Empirical evidence on the dynamic development of organic farming with respect to the underlying production structure is still rare and mostly based on partial measures of economic performance (see e.g. Jacobsen et al. 2005). So far, the issue of technical change and productivity development over time seems to be poorly investigated mainly because of a lack of adequate data at the farm level (most recently Sipilaeinen/Oude Lansink 2005).

Organic farming has its roots in alternative farming systems, and these systems have existed for many years also in Denmark based on the agreement that the impact of the production method on the surrounding environment should be included as a parameter of food quality. Denmark is currently one of the top-ten countries in Europe with regard to the share of organically cultivated area. In 2004 3166 organic farms accounted for about 6 percent of the total agricultural land whereas the average farm cultivated about 51 ha and the average number of livestock units was about 44 per farm (see DPD 2004 and KVL 2005). In the long run an increase in total organic production can be observed. In addition to financial support to organic farmers, the Danish government also discouraged conventional farming by levying high taxes on products such as insecticides and pesticides. In November 2003 support for organic farming was changed aiming at making the overall policy scheme more flexible and encouraging more farmers to convert. Nevertheless, in the last three to four years Denmark experienced a kind of stagnation with respect to the further development of the organic farming sector described as a ‘natural weakening’ by sectoral policy advisors (see e.g. Norfelt 2005): While the export of organic products could not been expanded also the domestic consumption stagnated resulting in a total surplus of organic production. After continuing growth the total number of organic farms declined in this period from 3714 in 2002 to 3166 in the year 2004. At the same time the overall political approach to the subsector of organic agriculture switched from an environmentally oriented to a market oriented approach (Norfelt 2005). Experts, however, doubt the effectiveness and logic of this approach and expect an enduring recession of organic farming in

Denmark.[1] This paper attempts to quantitatively measure the change in productivity for Danish organic farming in recent years by using panel data on 56 organic farms mainly engaged in milk production for the period 2002 to 2004. Section 2 gives a brief overview of recent developments in the organic farming sector in Denmark, section 3 summarises the modelling approaches as well as the main findings of most relevant economic studies on organic farming. Section 4 gives a brief theoretical review of the concepts of total factor productivity and market exit as well as outlines the underlying research hypotheses and the different models applied. Section 5 describes the data set and estimation procedures used followed by the exposition and discussion of the estimation results in section 6. Section 7 finally concludes.

[1] However, during the process of completing this research paper (July 2006) a slight ascent in overall organic farming could be noticed (i.e. a relative increase in prices and export demand).

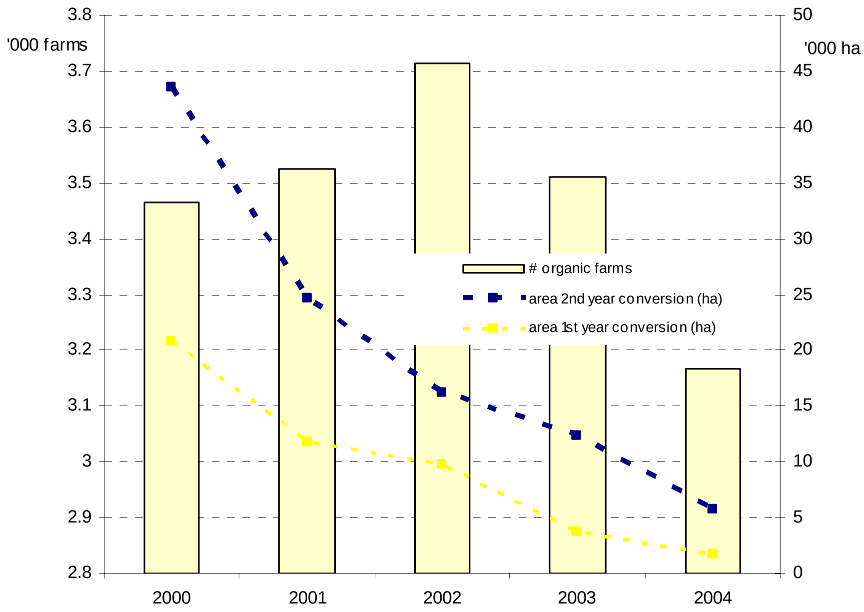
2. Organic Farming in Denmark – Sectoral Developments

In the last 10 to 15 years the total organic production in Europe nearly tripled (Hæring et al. 2004) whereas approximately 4 - 5% of the total agricultural area is organically cultivated. The highest share of organic production can be found in Austria, Denmark, Finland, Sweden and Switzerland. Analyses showed that the conversion rate in Europe has been driven by the effects of relatively high product prices and subsidy payments (Offerman/Nieberg 2002). However, type and level of subsidies paid vary from country to country: whereas e.g. the UK offers only support in the conversion period of about 100 Euro per hectar and year, others, as e.g. Switzerland, continue to pay an average hectar premium of up to 800 Euro per hectar and year. The average rate of subsidy payment decreased in the last years in several European countries which has been also due to the positive development of the relative competitiveness of organic farms compared to conventional farms.

The organically cultivated total area in Denmark increased dramatically until the late 1990s whereas in the period from 1998 to 2000 the largest amount of farms under conversion to organic farming was experienced. These growth rates led to ambitious expectations with respect to the future development of organic farming in Denmark: in 1999 the Organic Council forecasted an organic share of 11% of the total agricultural area for 2003 and a long-term share of even up to 30% (The Organic Council 1999). During this period of growth the highest increase in area cultivated was reached by large dairy farms mainly situated in the southern part of Jutland (see Jacobsen et al. 2005). However, since the year 2000 the rate of farms under conversion to organic farming is dramatically declining (see figure 1).

In the year 2003 only 62 new applicants were registered (DPD 2004) whereas 266 organic farms left the market – either by cessation of production or by converting back to conventional production. During the year 2004 the net number of organic farms exiting the market even increased by 69% to 344. Farms converting back to conventional production have been predominantly engaged in large scale dairy production and were mainly located on Jutland (Jacobsen et al. 2005). However, in the sub-sector of organic milk production the absolute number of farms decreased by 49 in 2004 (in total 476). Preliminary estimates for 2005 assume an ongoing decline in the total agricultural area organically cultivated mainly driven by the exit of dairy farms (DAAS 2005). At the same time (November 2003) the overall political approach to the subsector of organic agriculture switched from an inflexible, more environmentally oriented to a flexible, more market oriented approach (Norfelt 2005). The current support scheme aims at linking subsidy payments and environmental benefits mainly by 3 elements: (i) initial conversion support for the first two years of production, (ii) support for 'environmentally-favourable extensification' for a period of 5 years ('MB measure'), and (iii) support for 'environmentally friendly farming' ('MVJ measure'). Milk producing farms are not eligible to receive conversion support (Norfelt 2005). Experts, however, doubt the effectiveness and logic of this approach and expect an enduring recession of organic farming in Denmark.

Figure 1. Organic Farms and Area Under Conversion in Denmark 2000 – 2004



Source: DPD 2004.

The pronounced decline in organic farming in recent years is more or less unique throughout Europe (Nieberg et al. 2005, Jacobsen et al. 2005). Market observers name as the main factors for this decline falling product prices stemming from decreasing consumption and export demand as well as reduced support measures. With respect to organic milk production the price premium on milk was reduced in 2001 despite the introduction of a 100% organic cow feeding requirement. Currently produced organic milk in Denmark is utilised by a ratio of 50-70% in the manufacturing of organic products. With respect to organic crop production prices decreased by nearly 50% in the last years (Tvedegaard 2002). Part time farming already plays an important role for organic production in Denmark and the majority of farms converting to organic production in the future is expected to mainly belong to this subsector (Jacobsen et al. 2005). Such part time farmers earn a large amount of their total income outside organic farming which makes the dependence on subsidy payments less pronounced. The succes of the latter is on the other hand crucially determined by the actual labor productivity and consequently the rate of technical change realized in the future to reduce the workload by farming activities.

It became clear that large organic milk production accounts for the main part of current organic agriculture in Denmark, its ongoing importance is assumed by different sector observers. Because of this relative importance the following empirical analysis focuses organic milk farms all over Denmark. Explanations for the recent decline in organic production found in the relevant literature are solely oriented towards a demand side argumentation stressing the implications of declining or stagnating consumption and hence product price decreases (see most recently Jacobsen et al 2005). However, also supply side factors have to be stressed in order to fully understand the driving forces for the observed recession in Danish organic farming: significant organic overproduction reinforces ceteris paribus farm competition based on relative farm efficiency and the relative total factor productivity development over time. The individual organic farmer is concerned with relative profits and for the latter the relative efficiency of the agricultural operations is crucial. In addition, the mid to long term success of policy efforts to promote organic farming is crucially based on an adequate level of the individual farms' efficiencies (see also Tzouvelekas et al 2001). So far, the efficiency as well as the productivity developments in organic farming have not been investigated for Denmark and only rarely for other European countries (see section 3). The previously described developments in the sector suggest significant differences in farms' total factor productivities and their development over the last years.

3. Relevant Analyses and Research Desiderata

Economic research with respect to organic farming on the farm level has been started in the mid 1990s and can be basically divided into two strands: empirically oriented analyses mainly applying a multivariate framework and more consultancy oriented partial economic analyses.[2] Multivariate studies on the productivity of organic farming have been done on cotton, olive and durum wheat farms in Greece (Tzouvelekas et al. 2001a,b; 2002), on crop and livestock farms in Finland (Oude Lansink et al. 2002), on cereal farms in Italy (Madau 2005), and on Norwegian organic dairy systems (Flaten/Lien 2005) as well as with respect to Finnish dairy farms (Sipilaeinen/Oude Lansink 2005). Partial analyses using single productivity and cost measures have been conducted with respect to organic crop farms in France (Rainelli/Vermersch 2000) and organic farming in the Czech Republic (Jánský et al. 2003). Tzouvelekas et al (2001a) applied a stochastic production framework on a cross sectional data set of conventional and organic cotton farms in Greece for the year 1995-96 to reveal evidence on the technical, allocative as well as overall economic efficiency on farm level.

Estimating a Cobb Douglas production frontier the authors found relatively high scores for both farm types and a high inefficiency explaining power for the age and education of the farmers. Both types of farming exhibited a high allocative efficiency, however, organic farms in the sample were found to be less technically and consequently less overall efficient. The findings on the olive and durum wheat farms more or less confirmed these findings (Tzouvelekas et al. 2001b, 2002). Oude Landsink et al (2002) compared the efficiency of organic and conventional crop and livestock producers in Finland following a non-parametric approach by using panel data for the period 1994 to 1997. The results showed that the relative efficiency of organic farms is higher with respect to the organic frontier, but lower with respect to the overall frontier considering also conventional farms. Madau (2005) investigated the technical efficiency of cereal farms in Italy for 2000 as well as 2001 by estimating a stochastic Cobb Douglas production frontier for organic and conventional farms. The results confirmed earlier studies on a higher average efficiency of conventional farms. Flaten and Lien (2005) approximated the organic dairy farm management process by a stochastic dominance programming model incorporating sequential decisions. The authors concluded on a higher significance of production and institutional constraints

[2] Beside farm level studies there are different studies focusing the sectoral level of organic farming (see e.g. Lampkin et al. 1999, Offermann/Nieberg 2002 or Lohr/Salomonsson 2000).

than the degree of risk aversion for organic farming decisions in Norway. So far, the only contribution tackling the development of organic fams' efficiency over time was done by Sipilainen and Lansink (2005) by applying a stochastic distance frontier in a translog specification on a sample of conventional and organic dairy farms in Finland for the period 1995 – 2002. The results confirmed again a lower technical efficiency of organic farms and revealed that after an initial drop in farms' efficiencies in the period of conversion to organic farming, approximately 6 years after conversion farms' efficiencies start to increase again. The authors conclude on significant learning effects with respect to organic farming refering to the evidence found by innovation adoption studies (see e.g. Luh/Stefanou 1993). With respect to market entry and exit behaviour of organic farms Pietola and Lansink (2002) analysed factors determining the choice between standard and organic farming technology in Finland by applying a switiching-type Probit model. Their findings suggest that decreasing conventional product prices as well as increasing subsidy payments are significant factors for initiating the switch to organic farming which is more likely for farms cultivating a larger area and achieving relatively low yields. This implies an adverse selection problem for policy actions.[3]

Whereas the studies on organic farming in Finland have investigated market entry as well as post entry behaviour of organic farms no study so far has attempted to shed empirical light on factors and developments leading to farms exiting the organic farming sector. However, a growing body of literature examines the main factors determining the likelihood of business dissolution by modelling a measure of firm exit as a function of several variables designed to reflect structural incentives and barriers to market exit as well as individual firm characteristics. Here e.g. economies of scale, overall industry growth, profitability, market concentration, capital requirements, sunk costs, R&D, firm size as well as the firm's leverage ratio and its age are used as potential explanatory variables (see e.g. Audretsch 1994, 1995, 2000). Most recently several studies relate also a firm's relative level of technical inefficiency to the probability of exiting the market (Wheelock/Wilson 1995, Dimara et al. 2003, Tsionas/Papadogonas 2005).

Economic studies on the organic agricultural sector in Denmark have been more oriented at delivering policy advice by mostly conducting partial economic cost calculations and sectoral scenario descriptions with a strong agronomic focus (see e.g. Folk-

[3] The study by Klonsky and Smith (2002) investigated the entry/exit behaviour for California's organic farming sector more from a sectoral point of view.

mann/Poulsen 1998, Wynen 1998, Tvedegaard 1999, 2000, 2002, 2005, Kledal 2000, Norfelt 2005, Jacobsen et al 2005). Whereas Folkmann and Poulsen (1998) studied the requirements for competitive organic production in Denmark, Wynen (1998) analysed the sectoral and economywide consequences of a widespread adaption of organic farming. Extensive analyses and scenarios for the cost and profit situation of organic crop, milk, and pig production in Denmark were carried out by Tvedegaard (2000, 2002, 2005). The author focused the farm conversion period and concluded on the various price support levels required for setting appropriate conversion incentives. Kledal (2000) finally conducted interviews among conventional farmers to reveal evidence on the attitude towards converting to organic production and concluded on the potential for future organic farming in Denmark. Jacobsen et al (2005) described different scenarios for the future development of organic farming using partial cost calculations and single farm examples. Finally Norfelt (2005) gives a summary of the historical development and a brief description of the current economic situation of organic farming in Denmark. However, no multivariate empirical analysis on the farm level has been undertaken so far for Denmark to reveal evidence on the relative economic performance of organic farms by using e.g. a production or dual cost/profit framework.

The following analysis aims to contribute empirically as well as methodologically to the previously conducted studies on organic farming at the farm level by using panel data on 56 milk farms for the period 2002 to 2004. The estimation of a stochastic production frontier aims at filling the gap with respect to multivariate performance measures for the Danish organic sector. The development of the total productivity, technical change and technical and scale efficiency is further analysed by applying a time trends model specification as well as a general index specification by also considering the current discussion on functional consistency (see Barnett 2005 or Sauer 2006). We investigate the significance of different explanatory factors for the variance in technical change as well as efficiency change over time and try to conclude on the relative significance of policy support measures. We finally attempt to make inferences on the likelihood of organic market exit by using proxies for a potential farm exit. We account for small sample bias by using bias corrected resampling methods and link them to developments in policy relevant farm characteristics over the relevant period. Given the prevailing overproduction in the organic dairy sector and the long term policy goal of stimulating growth in organic production, beside setting incentives for farm conversion feasible policy measures could also be targeted on giving support for farms found to be likely 're-converters' to conventional production.

This, of course, only if a future strengthening in the demand for organic dairy products can be reasonabily expected.

4. Total Factor Productivity and Probability of Market Exit – Hypotheses and Modelling

The preceeding description of the current trends in the organic farming sector and the appraisal of economic studies available lead us to the following research hyoptheses:

Hypothesis 1: Significant differences in the organic farms' technical efficiencies and total factor productivities can be expected predominantly as a consequence of differing management abilities and states of technology conversion.

Hypothesis 2: A significant increase in the average total factor productivity has not taken place for organic milk production over the last years. However, because of learning effects among organic farmers a positive average technical change can be assumed for the sector.

Hypothesis 3: Because of the increased ability to afford technology improvements subsidy payments are expected to have a positive influence on the development of technical efficiency as well as technical change on organic farm level. Mixed evidence can be expected for the influence of off farm income as positive efficiency effects because of a softer budget constraint might be outweighed by negative efficiency effects because of a tighter labor constraint. However, a tighter labor constraint could on the other hand also imply positive efficiency effects because of incentives to work more productive and a softer budget constraint could also lead to negative efficiency effects because of disincentives to effective investments.

Hypothesis 4: The probability of organic market exit is expected to be negatively affected by an increase in subsidy payments received as well as an increase in total off farm income earned.

4.1. Time Varying Technical Efficiency

Following basically Farrell (1957), technical efficiency (TE) denotes a production unit's ability to achieve maximum output given its set of inputs and considering its production restrictions, i.e. exogenous determinants. Let us define the input sets of our organic milk production technology OM as I(y) = [x: (y, x) $\in$ OM] giving the sets of input vectors feasible with respect to our output vector y $\in$ $\mathbf{R}^{\mathbf{M}}_{+}$ where M = 1, 2, …, m. The output sets of our organic milk production technology OM are defined as O(x) = [y: (y, x) $\in$ OM] describing all sets of output vectors feasible for each input vector x $\in \mathbf{R}^{N}_{+}$ where N = 1, 2, …, n. The organic milk production frontier can be finally defined as a function:

$$Y(x) = f(x) = \max[y: y \in O(x)] = \max[y: x \in I(y)] \qquad [1]$$

Well known in the relevant literature and adhering to microeconomic theory our organic milk production frontier has to satisfy certain mathematical properties: (1) $f(0)=0$, (2) f is upper semi-continuous in $\mathbf{R}^{N}_{+}$, (3) $f(x)>0 \Rightarrow f(\lambda,x)\to+\infty \; if \; \lambda\to+\infty$, (4) $f(\lambda,x)\geq f(x),\lambda\geq 1 \; for \; x\in \mathbf{R}^{N}_{+}$ i.e. (weak) monotonicity in $\mathbf{R}^{N}_{+}$, (5) f(x) is quasi-concave in $\mathbf{R}^{N}_{+}$[4]. f(x) hence describes an organic milk production frontier depicting the maximum output that can be produced with any given input vector out of I(y). As with respect to our single production problem one output is produced, the input sets $I(y)=\{x: f(x)\geq y\}$ consist of all input vectors that can be used with the technology OM to produce at least the scalar organic milk output y. Further the input isoquants $\mathrm{IsoqI}(y)=\{x: f(x)=y\}$ consist of all input vectors that can be used to produce scalar organic milk output y and if radially contracted can *not* be used to produce the scalar organic milk output y. Finally the input efficient subsets $\mathrm{EffI}(y)=\{x: f(x)=y, x'\leq x \Rightarrow f(x')\}$ consist of all input vectors that can be used to produce the scalar organic milk output y and if radially contracted can *not* be used to produce the scalar organic milk output y. Such an organic milk production frontier provides the upper boundary of all organic milk production possibilities, i.e. every organic milk producer in the sample is located with his input/output combination on or beneath this frontier. Hence, the determination of relative technical efficiency with respect to organic milk production in Denmark is concerned with measuring the distance of each farmer from this production frontier.

Different parametric as well as non-parametric techniques to measure such relative efficiency are extensively described in the literature (see e.g. Khumbhakar/Lovell, 2000). As the stochastic frontier approach is capable of capturing measurement error and other statistical noise influencing the shape and position of the production frontier we consider it as superior in an agricultural production context largely influenced by randomly exogenous shocks as e.g. climatic influences. However, the stochastic approach to efficiency measurement is subject to prior decisions on the distributional form of the inefficiency component of the error term as well as the modelling of the underlying technology. The latter has to be specified by a particular functional form adhering to theoretical consistency as well as flexibility (see Sauer, 2006). Because of

---

[4] Implying convexity of the input sets IM(y).

a lack of significantly varying output and input prices Danish organic milk farming seems to be adequately modelled by the behavioural assumption of output maximisation and hence a production function framework. Hence, an output orientation of the frontier was chosen here.

The assumption maintained in time-invariant stochastic efficiency models (see e.g. Fried et al. 1993, and Greene 1993) that efficiency is constant through time is a relatively unrealistic modelling restriction with respect to a competitive agricultural production environment. Consequently, we model technical efficiency of organic milk production by applying a time varying stochastic error components approach (see Kumbhakar et al. 1991, Kumbhakar/Lovell 2000) using the flexible functional form of a translog production function

$$\ln y_{it} = \beta_{ot} + \sum_n \beta_n \ln x_{nit} + \sum_n \sum_k \beta_{nk} \ln x_{nit} \ln x_{kit} + \varsigma_t \ln c_{it} + v_{it} - u_{it} \qquad [2]$$

$$u_{it} = \gamma' z_{lit} + \varepsilon_{it} \qquad [3]$$

with y_{it} as the organic milk output of farm i at time t (t = 2002, 2003, 2004), x_{nit} as the variable input n (n = land, labor, materials, cows) of farm i at time t, c_{it} as the quasi-fixed input capital of farm i at time t and where random noise in the production process is introduced through the error component $v_{it} \sim iid\ N(0, \sigma_v^2)$ and the technical inefficiency component u_{it}.[5] The latter has a systematic component $\gamma' z_{it}$ associated with the (1xM) vector of exogenous variables z_{lit} (z = investments in capital and machinery, investments in milk quota, organic subsidies, veterinary expenses, external finance, external income, regional location) and γ as an (Mx1) vector of unknown scalar parameters to be estimated as well as a random component ε_{it}. By inserting [2] into [3] we obtain the single stage production frontier model avoiding inconsistency problems with respect to the econometric specification (see Khumbhakar/Lovell 2001)

$$\ln y_{it} = \beta_{ot} + \sum_n \beta_n \ln x_{nit} + \sum_n \sum_k \beta_{nk} \ln x_{nit} \ln x_{kit} + \varsigma_t \ln c_{it} + v_{it} - (\gamma' z_{it} + \varepsilon_{it}) \qquad [4]$$

[5] Capital input is modelled as quasi-fixed in the organic milk production process as the examined time period is rather small (3 years). A likelihood ratio test on the superior model specification was performed (see section 6).

with the nonnegativity requirement $u_{it} = (\gamma' z_{it} + \varepsilon_{it}) \geq 0$ modelled as $\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$ where the distribution of ε_{it} being bounded below by the variable truncation point $-\gamma' z_{it}$ (Battese/Coelli 1995 based on Huang/Liu 1994). The technical efficiency of the i-th producer at time t is given by

$$teff_{it} = \exp\{-u_{it}\} = \exp\{-\gamma' z_{it} + \varepsilon_{it}\} \qquad [5]$$

where a predictor is provided by

$$E[\exp\{-u_{it}\} \big| (v_{it} - u_{it})] = \left[\exp\{-\mu_{it} + ½\sigma^2\}\right] \left[\frac{\Phi\left[\left(\frac{\mu_{it}}{\sigma}\right) - \sigma\right]}{\Phi(\frac{\mu_{it}}{\sigma})} \right] \qquad [6]$$

where the mean $\mu_{it} = \dfrac{\sigma_v^2(\gamma' z_{it}) - \sigma_u^2(\varepsilon_{it})}{\sigma_v^2 + \sigma_u^2}$ and the variance $\sigma^2 = \dfrac{\sigma_v^2 \sigma_u^2}{\sigma_v^2 + \beta' \beta \sigma_u^2}$,

respectively.

We impose symmetry in inputs by $\beta_{nk} = \beta_{kn}$, homotheticity as well as homogeneity of degree 1 by $\sum_n \beta_n = 1, \sum_n \sum_k \beta_{nk} = 0$. Hence we estimate the translog frontier model in a variable as well as a constant returns to scale specification which enables us to reveal also evidence on the scale efficiency of farm i at time t

$$seff_{it} = teff_{it}^{vrs} / teff_{it}^{crs} \qquad [7]$$

4.2. Technical Change and Total Factor Productivity 1 – Time Trend Specification

Analysing the sign and magnitude of technical change for our panel of organic milk producers can be parametrically accomplished by including a time indicator in the time varying frontier model outlined above. By linking the stochastic frontier approach to a time trend specification we are hence able to disentangle the effect of technical change from that of technical efficiency change (Kumbhakar 1990, Battese/Coelli 1992). In the relevant literature a Hicks neutral technical change specification is differentiated from a non-neutral or biased technical change model specification. The latter allows for the investigation of the assumption that technical change is biased in favour of certain input(s) with respect to a single output production framework. By following this non-neutral modelling specification we consequently include beside first and second order time related terms t and t^2 also terms involving the interactions of the variable inputs and time.

$$\ln y_{it} = \beta_{ot} + \sum_n \beta_n \ln x_{nit} + \sum_n \sum_k \beta_{nk} \ln x_{nit} \ln x_{kit} + \varsigma_t \ln c_{it} + \chi_t t + \chi_{tt} t^2 + \delta_{nt} \sum_n \ln x_{nit} t + v_{it} - (\gamma_l' \sum_l z_{lit} + \varepsilon_{it}) \qquad [8]$$

The technical change index per farm and period is then obtained directly from the estimated parameters by simple calculations

$$tch_{it,t+1}^{tt} = \left\{ \left[1 + \frac{\partial(\beta_{ot} + \sum_n \beta_n \ln x_{nit} + \sum_n \sum_k \beta_{nk} \ln x_{nit} \ln x_{kit} + \varsigma_t \ln c_{it} + \chi_t t + \chi_{tt} t^2 + \delta_{nt} \sum_n \ln x_{nit} t + v_{it} - (\gamma' z_{it} + \varepsilon_{it}))}{\partial t_i} \right] * \left[1 + \frac{\partial(\beta_{ot+1} + \sum_n \beta_n \ln x_{nit+1} + \sum_n \sum_k \beta_{nk} \ln x_{nit+1} \ln x_{kit+1} + \varsigma_t \ln c_{it+1} + \chi_{t+1} t + \chi_{t+1,t+1} t^2 + \delta_{nt+1} \sum_n \ln x_{nit+1} t + v_{it+1} - (\gamma' z_{it+1} + \varepsilon_{it+1}))}{\partial t_{i+1}} \right] \right\}^{½} \qquad [9]$$

following basically Nishimuzu and Page (1982) as well as Coelli et al. (1998) and using the geometric mean to estimate the technical change index between adjacent periods t and t+1. Technical change is neutral if $\delta_{nt} = 0$ for all inputs n and can be decomposed into pure ($\chi_t + \chi_{tt} t$) and non-neutral technical change $\delta_{nt} \sum_n \ln x_{nit}$. In the case of non-neutral technical change the measure of the bias in technical change is simply

$$b_n^{tt} = \frac{\partial \ln X_{int}}{\partial t} = \frac{\delta_{nt}}{\theta_{int}} + \theta_{int}$$

where θ_{int} is the factor or input elasticity of input n. Technical change is biased towards input n as $b_n > 0$ and input n saving if $b_n < 0$. θ_{int} and b_n are both farm and time varying.

By observing that $d_i^t\left(x_{it}, y_{it}\right) = teff_{it} \neq d_i^{t`+1}\left(x_{it+1}, y_{it+1}\right) = teff_{it+1}$ where **x** and **y** are the input and output vectors[6] and d as the distance from the period t observation to the period t technology, the change in technical efficiency per farm and period is obtained by

$$effch_{it,t+1}^{tt} = teff_{it+1} / teff_{it} = \exp\left\{-\gamma' z_{it+1} + \varepsilon_{it+1}\right\} / \exp\left\{-\gamma' z_{it} + \varepsilon_{it}\right\} \qquad [11]$$

and correspondingly change in scale efficiency per farm and period by

$$seffch_{it,t+1}^{tt} = seff_{it+1} / seff_{it} = \frac{\left[\left(\exp\left\{-\gamma' z + \varepsilon\right\}\right)_{it+1}^{crs} / \left(\exp\left\{-\gamma' z + \varepsilon\right\}\right)_{it+1}^{vrs}\right]}{\left[\left(\exp\left\{-\gamma' z + \varepsilon\right\}\right)_{it}^{crs} / \left(\exp\left\{-\gamma' z + \varepsilon\right\}\right)_{it}^{vrs}\right]} \qquad [12]$$

Both indices – technical efficiency change by [11] and technical change by [9] – are then multiplied to obtain the Malmquist total factor productivity indezes (tfp) per farm and period as defined in distance notation by

$$tfp_{it,t+1}^{tt}\left(y_{it}, x_{it}, y_{it+1}, x_{it+1}\right) = \frac{d_i^{t+1}\left(y_{it+1}, x_{it+1}\right)}{d_i^t\left(y_{it}, x_{it}\right)} \left[\frac{d_i^t\left(y_{it+1}, x_{it+1}\right)}{d_i^{t+1}\left(y_{it+1}, x_{it+1}\right)} * \frac{d_i^t\left(y_{it}, x_{it}\right)}{d_i^{t+1}\left(y_{it}, x_{it}\right)}\right]^{½} = effch_{it,t+1}^{tt} * tch_{it,t+1}^{tt} \qquad [13]$$

and following Faere et al. (1994). Different likelihood ratio (LR) tests are applied using the common test statistic

$$LR = -2\left\{\ln[L(H_0) / L(H_1)]\right\} = -2\left\{\ln[L(H_0)] - \ln[L(H_1)]\right\} \qquad [14]$$

---

[6] Here, of course, we estimate the single output case.

where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function. By [14] we test for (i) the appropriatness of the flexible translog specification ($\sum\sum\beta_{nk}=0$), (ii) homotheticity of the production function ($\sum\beta_n=1$), (iii) linear homogeneity of degree 1 and constant versus variable returns to scale specification ($\sum\beta_n=1,\sum\sum\beta_{nk}=0$) respectively, and (iv) no technical change ($\chi_t=\chi_{tt}=\sum\delta_{tn}=0$). With respect to the underlying regression assumptions we further test for heteroscedasticity as well as serial correlation by a F-test formula following Wooldridge (2002). So far, the popular time trend (tt) model specification has been outlined. Nevertheless, there are other competing specifications with respect to the measurement of technical change and total factor productivity available (see e.g. Baltagi et al. 1995, Kumbhakar/Heshmati 1996, Kumbhakar et al. 2000, Baltagi/Rich 2003 or Kumbhakar 2004) which are mostly based on the seminal work by Baltagi and Griffin (1988).

4.3. Technical Change and Total Factor Productivity 2 – General Index Specification

Baltagi and Griffin (1988) proposed an econometric procedure for estimating a general index (gi) of technical change and resulting in a measure of total factor productivity growth which is generally found to be close to the divisia index as the productivity change directly calculated from the data (see Capalbo 1988). Most recently Kumbhakar (2004) extended this general index specification by adding the definition of tfp growth as an additional equation to be simultaneously estimated with the production or dual cost system. The translog production function incorporating the general index can be written as

$$\begin{aligned}\ln y_{it} &= \beta_{ot}+\sum_n\beta_n\ln x_{nit}+\chi_t a(t)+\sum_n\sum_k\beta_{nk}\ln x_{nit}\ln x_{kit}+\chi_{tt}a(t)^2\\ &+\sum_n\delta_{nt}\ln x_{nit}a(t)+\varsigma_t\ln c_{it}+\sum_l\gamma_l\ln z_{lit}+\varepsilon_{it}\end{aligned} \quad [15]$$

with y_{it} as the organic milk output of farm i at time t (t = 2002, 2003, 2004), x_{nit} as the variable input n (n = land, labor, materials, cows) of farm i at time t, c_{it} as the quasi-fixed input capital of farm i at time t, and z_{lit} (z = investments in capital and machinery, investments in milk quota, organic subsidies, veterinary expenses, external finance, external income, regional location). a(t) is the index of technical change and is modelled as

$$a(t) = a\sum_t \phi_t d_t \qquad [16]$$

where d are the year dummies. This gi model specification follows Kumbhakar (2004) and differs from the originally formulated by Baltagi and Griffin (1988) as the square term of the index $a(t)^2$ is explicitly included corresponding to the second order approximative nature of the translog production function. This implies that the gi model is obtained from the general tt specification as t is replaced by a(t). Technical change in the general index model is defined by

$$tch_{it,t+1}^{gi} = -\{a(t+1)-a(t)\}\{\chi_t + \chi_{tt}\{a(t+1)+a(t)\}\} - \{a(t+1)-a(t)\}\left(\sum_n \delta_{nt+1} \ln x_{int+1}\right) \qquad [17]$$

and is consequently both farm and time specific. As for the tt model technical change is Hicks neutral if $\delta_{nt} = 0$ for all inputs n. In the case of non-neutral technical change the measure of the bias in technical change for the gi specification follows again [10]. Total factor productivity growth is obtained by

$$tfp_{it,t+1}^{gi} = tch_{it,t+1}^{gi} + (1-\theta_{it+1}^{gi})\dot{y}_{it+1} \qquad [18]$$

where θ_{it+1}^{gi} denotes the scale elasticity for observation i at time t+1 corresponding to the sum of the individual input elasticities

$$\theta_{it}^{gi} = \sum_n \left(\partial \ln y_{it} / \partial \ln x_{int}\right) = \sum_n \left(\beta_n + \sum_k \beta_{nk} \ln x_{kit} + \delta_{nt} a(t)\right) \qquad [19]$$

and $\dot{y}_{it+1}$ as the estimated organic milk output for farm i at time t+1. In the gi specification efficiency changes are not explicitly estimated but can be recovered by following

$$effch_{it,t+1}^{gi} = tfp_{it,t+1}^{gi} / tch_{it,t+1}^{gi} \qquad [20]$$

by simply using the results obtained by equation [18] and equation [17]. As for the time trends specification we estimate our gi specification in a constant as well as a variable returns to scale formulation by applying the corresponding restrictions. Consequently we obtain finally farm and time specific measures of the change in the scale efficiency of the organic operations by following [12]. The preceding description of the time trend as well as general index model as well as earlier applications lead us to

Hypothesis 5: It is assumed that the gi model specification performs significantly better than the tt specification with respect to tracking the observed tfp growth in the organic milk sector.

4.4. Input Substitution

By using the estimates of the translog production functions' parameters from [8] and [15] we are able to empirically investigate the interrelations between the different variable inputs used (i.e. land, labor, materials, cows) as well as their change over time. The concept of the elasticity of substitution was designed as "a measure of the ease with which the varying factor can be substituted for others." (Hicks 1932) and hence a measure of the curvature of an isoquant. There are different schools of thought on the appropriate measure for the elasticity of substitution between inputs n and k in the context of a multiple-input production function. We apply the concept by Allen/Uzawa – also known as partial elasticity of substitution – defined as

$$\sigma_{nk}^{A} = ((\sum_{n} f_n x_n) / x_n x_k)(|h_{nk}| / |H|) \qquad [21]$$

where x_n and x_k are the quantities of the inputs, f_n is the marginal product, $|H|$ as the determinant of the bordered Hessian and $|h_{nk}|$ as the cofactor of f_{nk}. We further apply the measure proposed by Morishima defined as

$$\sigma_{nk}^{M} = (f_n / x_n)(|h_{nk}| / |H|) - (f_k / x_k)(|h_{nk}| / |H|) = (f_k x_k / f_n x_n)(\sigma_{nk}^{A} - \sigma_{kk}^{A}) \qquad [22]$$

which is asymmetric ($\sigma_{nk}^{M} \neq \sigma_{kn}^{M}$) (see Blackorby/Russell 1981 and 1989) and where $\sigma_{nk}^{A}, \sigma_{kk}^{A}$ are Allen/Uzawa elasticities of substitution. In general, factors that are substitutes by the Allen/Uzawa measure, will be substitutes by the Morishima measure; but factors that are complements by the Allen/Uzawa measure may still be substitutes by the Morishima measure. Thus, the Morishima measure has a bias towards treating inputs as substitutes (or, alternatively, the Allen/Uzawa measure has a bias towards treating them as complements; see also Thompson 1997).

4.5. Curvature Correctness

Different recent publications point to the importance of correct curvature of the estimated function in order to infer theoretically consistent policy recommendations (see Barnett 2004, Sauer 2006). As is well known, the necessary and sufficient condition for a specific curvature consists in the semi definiteness of the bordered Hessian matrix as the Jacobian of the derivatives with respect to x_n: if $\nabla^2 Y(x)$ is negatively semidefinite, Y is quasi-concave, where ∇^2 denotes the matrix of second order partial derivatives with respect to the normalized translog production model. The Hessian matrix is negative semi definite at every unconstrained local maximum. The conditions of quasi-concavity are related to the fact that this property implies a convex input requirement set (see in detail e.g. Chambers 1988). With respect to the translog production function curvature depends on the specific input bundle X_n, which can be easily verified by the corresponding bordered Hessian containing beside estimated parameters also observed input quantities (see e.g. Sauer 2006). Consequently, for some input bundles quasi-concavity may be satisfied but for others not and what can be expected is that the condition of negative semi-definiteness of the bordered Hessian is met only locally or with respect to a range of input bundles. With respect to our translog production models in [8] and [15] it has to be checked a posteriori for every input bundle that monotonicity and quasi-concavity hold. If these theoretical criteria are jointly fulfilled the obtained estimates are consistent with microeconomic theory and consequently can serve as empirical evidence for possible policy measures. With respect to the proposed translog production model quasi-concavity can be imposed at a reference point (usually at the normalized sample mean) following Jorgenson and Fraumeni (1981). By this procedure the bordered Hessian is replaced by the negative product of a lower triangular matrix **Δ** times its transpose **Δ'** (see in detail also Sauer 2006). Imposing curvature at the sample mean is then attained by redefining the parameters in [8] and [15] respectively to

$$\beta_{nk} = -\eta_{nk} + \beta_n \lambda_{nk} + \beta_n \beta_k \qquad [23]$$

where $\lambda_{nk} = 1$ if n = k and 0 otherwise and $\eta_{nk} = (\Delta\Delta')_{nk}$ as the nk-th element of $\Delta\Delta'$ with **Δ** a lower triangular matrix.[7] As our point of approximation is the sample mean all data points are divided by their mean transferring the approximation point to an (n + 1)-dimensional vector of ones. At this point the elements of **H** do not depend on the specific input price bundle. The estimation models of the translog production frontier

[7] Alternatively one can use Lau's (1978) technique by applying the Cholesky factorization Δ = -**LBL**' where **L** is a unit lower triangular matrix and **B** as a diagonal matrix.

time trend model as well as the translog production function general index model are then reformulated as follows

$$\begin{aligned}\ln\left(\frac{y}{y'}\right)_{it} &= \beta_\alpha + \sum_n \beta_n \ln\left(\frac{x}{x'}\right)_{nit} + \sum_n\sum_k (-\eta_{nk} + \beta_n\lambda_{nk} + \beta_n\beta_k)\ln\left(\frac{x}{x'}\right)_{nit} \ln\left(\frac{x}{x'}\right)_{kit} + \varsigma \ln\left(\frac{c}{c'}\right)_{it} \\ &+ \chi_t t + \chi_{tt} t^2 + \delta_{nt} \sum_n \ln\left(\frac{x}{x'}\right)_{nit} t + v_{it} - \left[\gamma_l' \sum_l \left(\frac{z}{z'}\right)_{lit} + \varepsilon_{it}\right]\end{aligned} \quad [24]$$

and

$$\begin{aligned}\ln\left(\frac{y}{y'}\right)_{it} &= \beta_\alpha + \sum_n \beta_n \ln\left(\frac{x}{x'}\right)_{nit} + \chi_t a(t) + \sum_n\sum_k (-\eta_{nk} + \beta_n\lambda_{nk} + \beta_n\beta_k)\ln\left(\frac{x}{x'}\right)_{nit} \ln\left(\frac{x}{x'}\right)_{kit} \\ &+ \chi_{tt} a(t)^2 + \sum_n \delta_{nt} \ln\left(\frac{x}{x'}\right)_{nit} a(t) + \varsigma \ln\left(\frac{c}{c'}\right)_{it} + \sum_l \gamma_l \ln\left(\frac{z}{z'}\right)_{lit} + \varepsilon_{it}\end{aligned} \quad [25]$$

However, it becomes obvious that the elements of η_{nk} = $(\Delta\Delta')_{nk}$ are nonlinear functions of the decomposed Hessian matrix, and consequently the resulting normalized translog models become nonlinear in parameters. Hence, linear estimation algorithms are ruled out even if the original function is linear in parameters. By this "local" procedure a satisfaction of consistency at most or even all data points in the sample can be reached. The transformation in [23] moves the observations towards the approximation point and thus increases the likelihood of getting theoretically consistent results at least for a range of observations (see Ryan/Wales 2000).

4.6. Factors for Total Productivity Change – Multiple Equations Systems

With respect to policy measures it is relevant to reveal the driving as well as hindering forces for technical change, the development of relative efficiency, as well as the change in total factor productivity on the organic farm level. The time trend frontier specification described earlier accounts for technical inefficiency explaining factors from a static perspective, the same holds for the modelling of exogoneous production factors as control variables in the general index specification leaving aside the analysis from a more dynamic perspective. However, as these models do not focus the factors for the development in total factor productivity and its components over time we try to stochastically model such relationships by applying a multi equations linear regression procedure using the development in technical change, the development in technical efficiency as well as the development in scale efficiency as dependent variables:

$$
\begin{aligned}
tch_{it}^{s} &= \sum_{u} \kappa_{tch} x_{uit} + \varepsilon_{itch} \\
effch_{it}^{s} &= \sum_{u} \kappa_{effch} x_{uit} + \varepsilon_{ieffch} \\
sceff_{it}^{s} &= \sum_{u} \kappa_{sceff} x_{uit} + \varepsilon_{isceff}
\end{aligned}
\qquad [26]
$$

where s denotes the specific model used: time trends (tt) or general index (gi) specification, and u is an index for the relative development of the following explanatory variables X during the specific time period(s): investments in capital and machinery, investments in organic milk quota, organic subsidies received, veterinary expenses, external finance, external income farmer, external income other family members, total external income including rents and other transfer payments received. A simultaneous equation approach seems adequate as the total productivity components are assumed to be affected by the same farm specific factors as well as stochastic residuals at the same point in time. Consequently, the variations in the unexplained error term are somehow linked over the different single regressions. A Breusch-Pagan test is applied to test for the significance of this underlying modelling hypothesis. As the underlying productivity models in [24] and [25] already consider the likely covariances between farm efficiency and potentially inefficiency explaining factors X_u, modelling inconsistencies are avoided by this multi equations procedure (see Kumbhakar/Lovell 2000). As the dependent variables by definition take values greater than zero we further check for the consistency of our approach by also estimating a censored Tobit model for every productivity component and model specification and test for its significance compared to the model outlined in [26]. To test finally for the robustness of our estimates obtained by [24] to [26] we further apply a simple stochastic resampling procedure based on bootstrapping techniques (see e.g. Efron 1979 or Efron/Tibshirani 1993). This seems to be necessary as our panel data sample consists of a (rather) limited number of observations. If we suppose that $\hat{\Psi}_n$ is an estimator of the parameter vector ψ_n including all parameters obtained by estimating [26] based on our original sample of 112 observations (period 2002-2003 and period 2003-2004: 112 observations) $X = (x_1, \ldots, x_n)$, then we are able to approximate the statistical properties of $\hat{\Psi}_n$ by studying a sample of 1000 bootstrap estimators $\hat{\Psi}_n(c)_m, c = 1, \ldots, C$. These are obtained by resampling our 112 organic farm observations – with replacement –

from X and recomputing $\hat{\Psi}_n$ by using each generated sample. Finally the sampling characteristics of our vector of parameters is obtained from

$$\hat{\Psi} = \left[\hat{\Psi}_{(1)m}, \ldots, \hat{\Psi}_{(1000)m} \right] \qquad [27]$$

As is extensively discussed by Horowitz (2001) or Efron and Tibshirani (1993), the bias of the bootstrap as an estimator of $\hat{\Psi}_n$, $B_{\tilde{\psi}} = \tilde{\Psi}_n - \hat{\Psi}_n$, is itself a feasible estimator of the bias of the asymptotic estimator of the true population parameter ψ_n.[8] This holds also for the standard deviation of the bootstrapped empirical distribution providing a natural estimator of the standard error for each initial parameter estimate. By using a bias corrected boostrap we aim to reduce the likely small sample bias in the initial estimates.

A steady decline in an organic farm's productivity over time can lead - beside other factors - to a market exit of the farm. The aim of policy measures targeted to promote organic agricultural production should be to foil such detrimental developments. Hence, our forth modelling stage deals with the determination of policy relevant factors for an increasing likelihood of organic market exit.

4.7. Probability of Market Exit – Bivariate Probit Model

There is a significant amount of work on exit and survival of firms originating from the influential papers by Audretsch (1995) and Audretsch and Mahmood (1994, 1995). It is widely assumed that inefficient producers cannot survive in the long run provided the forces of competition in the relevant sector are reasonably strong (see e.g Wheelock/Wilson 1995 or Dimara et al. 2003). With respect to the empirical investigation of this phenomenon different proxies for the likelihood of market exit were found to be significant in the relevant literature (see e.g. Dunnes/Roberts 1991, Mayer/Chappel 1992, Wagner 1994, Mahmood 2000, Fotopoulos/Louri 2000 and Segarra/Callejón 2002). By lacking adequate data on organic farms' market exit for the period investigated we build on these earlier findings and use the development in the farms' total factor productivity as well as the development in the farms' leverage as the ratio of debt to total assets as proxies for the probability of exit. Hence our underlying assumption is that organic farms showing a low and steady declining total factor productivity in the investigated period as well as showing a high and steady increas-

[8] Hence the bias-corrected estimator of ψ_n can be computed by $\hat{\psi}_n - B_{\tilde{\psi}} = 2\hat{\psi} - \tilde{\psi}$.

ing leverage ratio are most likely exiting organic production in the mid to long term future. The analytical challenge is to detect policy relevant farm characteristics which are significantly linked to a steady decline in total factor productivity and a steady increase in the leverage ratio on farm level.

Tsionas/Papadogonas (2005) were the first to explicitly link stochastic measures of technical efficiency to the likelihood of market exit whereas the results of many previous studies suggested that high profits and correspondingly low costs as well as high firm productivity have a negative impact on exit behaviour (see Dunne/Roberts 1991, Mayer/Chappel 1999, Doi 1999, and Audretsch et al. 2000). By using the more comprehensive measures of farms' total factor productivity we try to contribute to this line of empirical research by constructing a binary proxy - *exittfp* - for the likelihood of organic market exit based on a relatively low and steady declining tfp score estimated by the models in [24] and [25] for the total period. On the other hand a high level of debt - i.e. a high leverage ratio - requires high interest payments, thus increasing firm risk and reducing the likelihood of survival (Fotopoulos/Louri 2000). Hence, we use as a second proxy for the probability of organic market exit the binary variable *exitlev* reflecting a relatively high and steady increasing leverage ratio calculated by using observed data. We regress these market exit proxies on potentially explaining factors X by applying a bivariate probit model (Kiefer 1982, Greene 1996) described by

$$\begin{aligned} exittfp_i &= \sum_v \zeta_{tfp} x_{vi} + \varepsilon_{itfp}, \quad exittfp_i = 1 \ \text{ if } exittfp_i > 0, 0 \text{ otherwise} \\ exitlev_i &= \sum_v \zeta_{lev} x_{vi} + \varepsilon_{ilev}, \quad exitlev_i = 1 \ \text{ if } exitlev_i > 0, 0 \text{ otherwise} \end{aligned} \qquad [28]$$

where X denotes potentially explanatory factors measured by their relative development over the study period: the change in investments in capital and machinery, the change in organic milk quota investments, the change in organic subsidies received, the change in external finance, the change in total revenue as a scale proxy (see Hughes 1994, Audretsch et al. 2000), the change in external income by the farmer, the change in external income by other family members, the change in total external income including rents and other transfer payments received, as well as the years the current farmer operates the organic farm as a proxy for the age of the farm (see Audretsch 1994 and 1995, Wagner 1994, and Agarwal 1997). The model in [28] allows for a simultaneous estimation of the two probit models based on the assumption that the disturbances are correlated in the same spirit as outlined for the seemingly unrelated regression model in [26]. The log-likelihood function and its marginal derivatives are described in Greene (2000). We apply a likelihood ratio testing procedure to investigate the statistical relevance of the underlying assumption of non-zero correlation of the disturbances. To test finally for the robustness of our estimates obtained by [28] we again apply a simple bootstrap. This seems to be necessary as our panel data sample consists now of 56 observations (as we model the relative developments over the period of 2002 to 2004). If we consequently suppose that $\hat{\Psi}_n$ is an estimator of the parameter vector ψ_n including all parameters obtained by estimating [28] based on our original sample $X = (x_1, ..., x_n)$, then we are able to approximate the statistical properties of $\hat{\Psi}_n$ by studying a sample of 1000 bootstrap estimators $\hat{\Psi}_n(c)_m, c = 1, ..., C$ following the procedure outlined above.

5. Data and Estimation Procedures

We use data on a panel of 56 organic milk farms in Denmark for the years 2002 to 2004 (see KVL, 2005). The organic farms were selected by a stratified random sampling procedure out of a total population of approximately 480 organic milk farms all over Denmark. Basic characteristics of the average organic farm in the total sample as well as for the individual years is shown by table 1.

Table 1. The Average Sample Farm

Farm Characteristics – Statistical Mean	Total Sample (n = 168)	Year 2002 (n = 56)	Year 2003 (n = 56)	Year 2004 (n = 56)
Total Revenue ('000 DKK)	2,807.490	2,717.717	2,749.137	2,955.617
Total Milk Revenue ('000 DKK)	2,083.749	2,043.989	2,089.619	2,117.638
Labor (hours per year)	4,991.06	4,973.25	4,988.857	5,011.071
Cows (n)	103.762	100.554	104.554	106.179
Material (DKK)	521,898.6	527,529.9	516,482.4	521,683.5
Land (ha)	137.711	135.762	133.697	143.675
Capital (DKK)	1.29e+07	1.21e+07	1.27e+07	1.40e+07
Investments (DKK)	1,279,805	824,001.6	974,209.6	2,041,203
Investment in Milk Quota (DKK)	177,538.8	109,561.8	208,806.5	214,248.1
Organic Subsidies (DKK)	84,860.21	87,697	80,181.05	86,702.57
Veterinary Expenses (DKK)	54,636.72	50,746.18	56,142.55	57,021.43
External Finance (DKK)	1,126,260	631,147.2	1,072,400	1,675,232
Total External Income (DKK)	102,039	102,371	96,800.45	106,946.9
Leverage Ratio (Debt/Total Assets in %)	65.15	63.77	65.11	66.56
Farm Location (1: Jutland, 0: Sealand, Fynen)	0.946	0.946	0.946	0.946
Age of Farmer (years)	46.268	45.268	46.268	47.268
Years Farmer is Operating the Farm (n)	20.375	19.375	20.375	21.375

1: Base year 2002; 2: 1 DKK = 0.135 Euro (31.12.2002).
3: Producer price index for agricultural materials p.a. 2003: 102.48, 2004: 109.64; general inflation % p.a. 2003: 2.1, 2004: 1.2; price index for milk and dairy products p.a. 2003: 104.95, 2004: 105.29; price index for machinery p.a. 2003: 96.39, 2004: 92.42 (sources: OECD, Danmark Statistic).

All monetary values have been adjusted with respect to the relevant base year prices of 2002. See appendix A1 for a full descriptive statistic for the total sample of organic milk farms. The average farm in the sample shows a total revenue of about 2.8 Mio DKK where about 74% are due to milk production. The average organic farm used in total nearly 5000 labor hours per year, had a herd size of about 104 cows over the year and cultivated about 138 ha land. Materials, as the sum of the expenses for seed, fertilizer, chemicals, fodder as well as organic nutrients purchased, were about 520 000 DKK per year. For the capital input over the year we use the yearly average of total agricultural assets (as a sum of real property, livestock, equipment and stocks in store) per farm in prices of the base year 2002.[9] Hence, the average farm in the total sample showed a quasi-fixed capital input (or capital stock) of about 12.9 Mio DKK p.a. Total investments over the year were nearly 1.28 Mio DKK per farm whereas about 14% of the total sum had been invested in milk quota. The average amount of organic subsidies were about 85 000 DKK, veterinary expenses about 55 000 DKK, and the total amount of income earned outside of agricultural operations were about 100 000 DKK per year and farm. The average farm in the total sample showed further a leverage ratio (the ratio of debt to total assets) of more than 65% implying a total external finance of about 1.13 Mio DKK per year. The average leverage ratio in the sample increased over the sample years (from 63.8% in 2002 to nearly 66.6% in 2004). The average organic milk farm was finally located on Jutland, the farmer's age was about 46 and the latter run the farm for more than 20 years.

The econometric estimations have been pursued as follows: In a first step we estimate the time varying error components approach in the time trends specification as well as the general index production function model. As a proxy for total output we use total revenue generated which we regress on the variable inputs, quasi-fixed input and other exogenous determinants by maximum likelihood (time trends) as well as iterative seemingly unrelated nonlinear least square regression (general index) procedures. The technical efficiency estimates obtained from the error components model are simultaneously regressed on potentially inefficiency variance explaining factors (see also section 4.1. and 4.2.) To reveal evidence on the driving forces for developments in total factor productivity subsequently the multiple equations system (see section 4.6.) is estimated by a bootstrapped iterative seemingly unrelated linear least square regression procedure using the relative changes (2002 to 2004) in the estimated variables technical change, efficiency change, and scale efficiency change as dependent variables both for the time trends as well as the general index specification. Finally we estimate the bivariate probit model (see 4.7.) by a bootstrapped but linear least square iterative seemingly unrelated procedure to get quantitative evidence on the driving forces for an increased probability of organic market exit. Here we use the relative level and change in total factor productivity as well as the relative level and change in the farms' leverage ratio over the period to define the two binary dependent variables *exittf*p and *exitlev* according to [29]

---

[9] Because of a lack of data (i.e. replacement costs, depreciation rates) we were not able to use more sophisticated capital measurement techniques as e.g. the perpetual inventory method. However, as we define capital as a quasi-fixed input and incorporate it as a single term along with investments in the estimations we assume that potential measurement errors are relatively insignificant. Such an approximative procedure is followed by several studies in the field.

$$exittfp_i = \begin{cases} 1 \; if \;\; \mathrm{tfp}_{i,0203} < \mathrm{tfp'}_{0203} \wedge \mathrm{tfp}_{\;i,0304} < \mathrm{tfp}_{\,i,0203} \\ 0 \text{ otherwise} \end{cases}$$

$$exitlev_i = \begin{cases} 1 \; if \;\; \mathrm{lev}_{\,i,02} > \mathrm{lev'}_{02} \wedge \mathrm{lev}_{\,i,04} > \mathrm{lev}_{\,i,02} \\ 0 \text{ otherwise} \end{cases} \qquad [29]$$

where e.g. tfp'_{0203} denotes the average total factor productivity change (over both model specifications) for the period 2002 to 2003 in the sample and lev'_{02} the average leverage ratio for the year 2002 in the sample.[10]

[10] All models were estimated by using the software STATA or Excell Premium Solver.

6. Results and Discussion

We estimated 4 different models. The individual model and parameter estimates are shown in table A2 to A6 in the appendix. All model specifications showed to be significant at a satisfying statistical level. For the time trends as well as general index model more than 70% of all estimated parameters are statistically significant. As the unrestricted estimation of the production frontiers led to heavily theoretically inconsistent results curvature correctness was imposed at the sample mean a priori to estimation. Monotonicity and quasi-concavity was then checked for every observation a posteriori to estimation. Consequently, all estimated specifications showed to be theoretically consistent for every observation in the sample (see appendix table A2 and A3 for the bordered principal minors at the sample mean). A likelihood ratio test confirmed the chosen functional form of a flexible translog (see table 2, 1). Homotheticity of the underlying production function could not been rejected in a single hypothesis framework, but was significantly rejected by the joint test for linear homogeneity, respectively constant returns to scale (see table 2, 2 and 3). The hypothesis of no technical change in the sample was rejected at the 1%-level, the same was found for the likelihood ratio test of the underlying modelling assumption of treating capital as a quasi-fixed input (table 2, 4 and 5).

Heteroscedasticity of the error terms was rejected at the 1%-level of significance, the same was found for serial correlation using a F-test formula (table 2, 6 and 7). With respect to the seemingly unrelated estimation procedure we further tested for independent disturbances in the multiple equation systems applying a Breusch Pagan test statistic. However, the independence hypothesis was rejected at a significant level for both models (table 2, 9). Finally a likelihood ratio test procedure confirmed the applicability of the chosen bivariate probit model frame by rejecting the hypothesis of zero correlation of the disturbances (table 2, 10).

Table 2. Hypotheses Tests

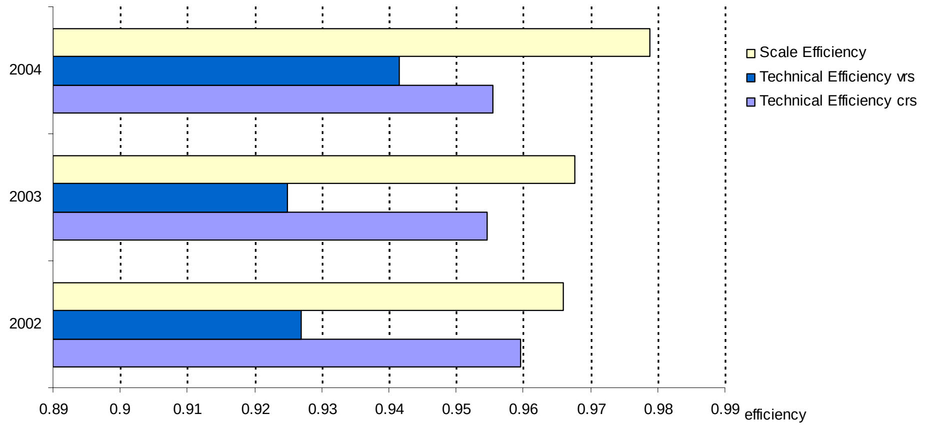
H_0 (LR-test formula)	χ^2 value
1) "CobbDouglas specification"	80.46*** (rejected)
2) "homotheticity of production function ($\beta_{lab}+\beta_c+\beta_m+\beta_l=1$)"	1.59 (not rejected)
3) "linear homogeneity of production function / constant returns to scale specification" ($\beta_{lab}+\beta_c+\beta_m+\beta_l=1$, $\beta_{lablab}+\beta_{labc}+\beta_{labm}+\beta_{labl}=0$, $\beta_{cc}+\beta_{labc}+\beta_{cm}+\beta_{cl}=0$, $\beta_{mm}+\beta_{labm}+\beta_{cm}+\beta_{ml}=0$, $\beta_{ll}+\beta_{labl}+\beta_{cl}+\beta_{ml}=0$)"	73.65*** (rejected)
4) "no technical change ($\chi_t=\chi_{tt}=\delta_{labt}=\delta_{ct}=\delta_{mt}=\delta_{lt}=0$)"	25.60*** (rejected)
5) "capital specification as variable input"	26.16*** (rejected)
6) "heteroscedasticity in panel data"	764.63*** (rejected)
H_0 (F-test formula)	F value
7) "no autocorrelation in panel data"	2.059 (not rejected)
H_0 (BP-test formula)	χ^2 value
9) "independent error terms – time trend model"	31.896*** (rejected)
"independent error terms – general index model"	51.755*** (rejected)
H_0 (LR-test formula)	χ^2 value
10) "zero correlation of error terms – probit model"	48.128*** (rejected)

*,**,***: significance at 10, 5, and 1 % -level

6.1. Total Factor Productivity, Technical Change and Technical Efficiency

In a first estimation step the time varying error components approach was used by applying a time trends model in a constant as well as variable returns to scale specification. Figure 2 summarizes the technical and scale efficiency scores for the sample of organic milk producers. The mean technical efficiency was found to be the lowest in 2003 with a value of about 0.924 for the variable and 0.954 for the constant returns to scale specification. However, it slightly increased for the most current year 2004 up to 0.941 and 0.955 respectively varying between a range of 0.678 and 0.999 and 0.671 and 0.999 respectively. The scale efficiency on farm level consequently increased from a mean value of 0.965 in 2002 to about 0.979 in 2004.

Figure 2. Mean Technical and Scale Efficiency per Year



With respect to the explanation of the variance in (static) inefficiency for the year 2004 the analysis showed that the amount of total investments by the farm and the amount of externally generated total income including rents and transfer payments have a positive effect on the farm's technical efficiency (see also appendix table A2). This could be due to a softer budget constraint faced by the farm with respect to new technology investments as well as a higher state of technology for organic farms already willing and capable to invest in advanced technology in the past. On the other hand it was found that the amount of externally earned income by the family members – i.e. predominantly wage income - negatively affects farms' relative technical efficiency. One reason for this finding could be that family members heavily engaged in off farm activities supply far less labor hours to on farm activities implying an increased likelihood of labor shortages at times where labor demanding activities are scheduled.

Despite the reference to a relatively short time period (3 years)[11] the following results on the development of total factor productivity, technical change, and efficiency change over time deliver valuable insights in the level and structure of organic farms' relative productivity. Table 3 gives a detailed summary of the development of the

[11] No other complete panel data set is currently available for organic farms in Denmark.

various tfp components over time measured by the alternative model specifications. As outlined in section 4.1. and 4.2. we estimated two alternative models in a variable and constant returns to scale specification for the total period of time as well as for the individual periods:

(i) Over all estimated models the change in the mean *efficiency* on farm level was found to range from -0.4% to +2.1% for the period 2002/2003, from +0.4% to +8.9% for the period 2003/2004, and from -0.1% to +5.1% for the total period 2002 to 2004. No clear difference was found with respect to the scale specifications but with respect to the alternative models chosen: the results by the general index model indicate a clear increase in efficiency over the individual as well as the total time period whereas the time trend model delivered mixed evidence. However, taking only the more significant variable scale specifications into account (see LR testing in table 2, 3) we can conclude that a considerable improvement in efficiency took place in organic milk production in Denmark over the total period investigated.

(ii) The results on the change in the organic farms' *scale efficiency* show positive rates for all periods investigated as well as all models tested. An increase in scale efficiency up to 0.4% was found for 2002/2003, up to 1.2% for 2003/2004, and up to 1% for the total period 2002 to 2004. We can therefore conclude on a slight improvement in the relative efficiency of the scale of organic milk production over the total period.

Table 3. Total Factor Productivity Decomposition – Different Periods and Alternative Models

Time period	2002 – 2003														
Model		Time Trend							General Index						
Specification	Divisia Index[3]	Constant Returns to Scale			Variable Returns to Scale				Constant Returns to Scale			Variable Returns to Scale			
Measure		TFP[1]	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH	TFP	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH
Mean	0.999[2] (-0.1%)	0.942 (-5.8%)	0.946 (-5.4%)	0.996 (-0.4%)	0.960 (-4%)	0.961 (-3.9%)	0.999 (-0.1%)	1.003 (+0.3%)	1.014 (+1.4%)	0.993 (-0.7%)	1.021 (+2.1%)	1.013 (+1.3%)	0.998 (-0.2%)	1.014 (+1.4%)	1.004 (+0.4%)
StErr	0.005***	0.006***	0.003***	0.006***	0.008	0.003***	0.008***	0.005***	0.079***	0.001***	0.081***	0.079***	0.001***	0.079***	0.003***
Min	0.986	0.787	0.878	0.831	0.793	0.884	0.833	0.950	0.844	0.992	0.850	0.843	0.993	0.843	0.994
Max	1.014	1.048	1.048	1.127	1.138	1.003	1.199	1.199	1.268	0.994	1.278	1.265	0.999	1.266	1.011

Time period	2003 – 2004														
Model		Time Trend							General Index						
Specification	Divisia Index[3]	Constant Returns to Scale			Variable Returns to Scale				Constant Returns to Scale			Variable Returns to Scale			
Measure		TFP[1]	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH	TFP	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH
Mean	1.006 (+0.6%)	0.997 (-0.3%)	0.992 (-0.8%)	1.004 (+0.4%)	1.006 (+0.6%)	0.987 (-1.3%)	1.019 (+1.9%)	1.012 (+1.2%)	1.087 (+8.7%)	0.998 (-0.2%)	1.089 (+8.9%)	1.087 (+8.7%)	0.998 (-0.2%)	1.089 (+8.9%)	1.001 (+0.1%)
StErr	0.009***	0.008	0.003***	0.006***	0.009	0.003***	0.007***	0.003***	0.167***	0.001***	0.167***	0.166***	0.001***	0.166***	0.003***
Min	0.990	0.853	0.935	0.866	0.852	0.931	0.860	0.967	0.869	0.998	0.871	0.867	0.998	0.868	0.992
Max	1.041	1.243	1.044	1.205	1.236	1.032	1.221	1.095	1.799	0.999	1.803	1.801	0.999	1.803	1.007

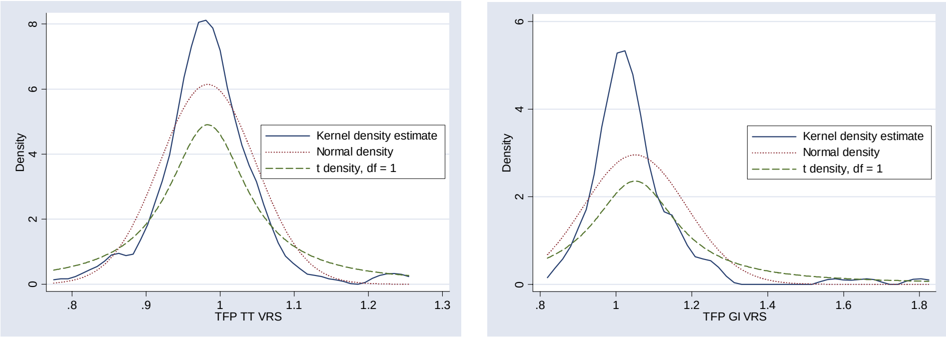
Time period	Total Period (2002 – 2004)														
Model		Time Trend							General Index						
Specification	Divisia Index[3]	Constant Returns to Scale			Variable Returns to Scale				Constant Returns to Scale			Variable Returns to Scale			
Measure		TFP[1]	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH	TFP	TCH	EFFCH	TFP	TCH	EFFCH	SEFFCH
Mean	1.002 (+0.2%)	0.962 (-3.8%)	0.963 (-3.7%)	0.999 (-0.1%)	0.987 (-1.3%)	0.971 (-2.9%)	1.017 (+1.7%)	1.010 (+1.0%)	1.050 (+5%)	0.995 (-0.5%)	1.055 (+5.5%)	1.050 (+5%)	0.998 (-0.2%)	1.051 (+5.1%)	1.002 (+0.2%)
StErr	0.008***	0.056***	0.022***	0.052***	0.061***	0.019***	0.060***	0.037***	0.135***	0.003***	0.135***	0.134***	3.34E-04***	0.135***	0.003***
Min	0.986	0.704	0.903	0.727	0.729	0.903	0.833	0.950	0.844	0.992	0.850	0.843	0.993	0.843	0.992
Max	1.041	1.089	1.017	1.150	1.172	1.008	1.218	1.199	1.799	0.999	1.803	1.801	0.999	1.803	1.011

1: TFP – Total Factor Productivity, TCH – Technical Change, EFFCH – Efficiency Change; 2: *,**,***: significance at 10, 5, and 1 % -level, 3: calculated based on observed values.

(iii) *Technical change* was found to be in a range from -5.4% to -0.2% for the period 2002/2003, in a range from -0.2% to -1.3% for the period 2003/2004, and in a range from -0.2% to -3.7% for the total period 2002 to 2004 (mean values). No clear difference was found with respect to the scale specifications but again with respect to the alternative models chosen: the results by the time trends model clearly indicate a decline in the rate of technical change on farm level in the individual as well as in the total time period whereas the results by the general index model were found to be not that pronounced but still significantly negative. To conclude and by refering only to the variable returns specifications it became clear that there has been a significant decline in the rate of technical change in organic milk production in Denmark over the total period investigated.

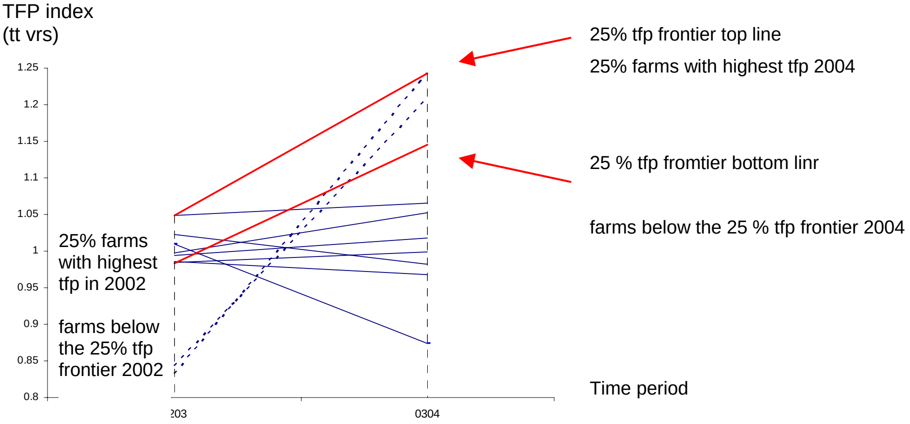
(iv) Based on these individual performance measures the change in *total factor productivity* for the individual as well as total time period investigated was found to vary significantly between the alternative models tested. Whereas the general index model in both scale specifications indicates a clear improvement in the mean total factor productivity for the organic milk farms – of about 1.3% in 2002/2003, 8.7% in 2003/2004, as well as 5% for the total period investigated – the time trends model delivered rather mixed results: here a clear negative change in the mean total factor productivity was found for 2002/2003 (in the range of -5.8% to -4%) and for the total period (in the range of -3.8% to -1.3%) whereas the mean total factor productivity for 2003/2004 more or less showed to be positive (a range of -0.3% to +0.6%). Overall it can be concluded that mixed results were found for the development of the mean total factor productivity in the organic milk sector. Figures 3a and 3b illustrate the distribution of the tfp indezes for the total period 2002 to 2004 obtained by the different estimation models for the more significant variable scale specification.

Figure 3a 3b. Kernel Density Distribution TFP - TT VRS / GI VRS



If we look on the frontier of the farms with the highest total factor productivity in the sample it becomes clear that there has been considerable fluctuation over time with respect to the farms on the frontier. This is illustrated by figure 4: the organic milk farms part of the frontier defined by the highest tfp in 2002/2003 fall all back below the 25% tfp frontier in 2003/2004 (see straight lines). The farms forming the 25% tfp frontier in 2003/2004 catched up with respect to their status in 2002/2003 far below the frontier (see dotted lines).

Figure 4. TFP Frontier Farms – TT VRS Model



If we further compare the tfp estimates for the total period with the tfp divisia index calculated based on observed values (-0.1% for 2002/2003, +0.6% for 2003/2004, and +0.2% for the total period) we find mixed evidence with respect to the most accurate model specification for the sample of organic farmers: the general index model shows to be more accurate with respect to reflecting the sign (i.e. direction) of the tfp change, the time trends model shows to be more accurate with respect to explaining the absolute difference (regardless the sign of change) in tfp changes. Table 4gives the rank correlations between the different indizes estimated for the individual organic farms for the total period.

Table 4 Rank Correlations – TFP Indices

		Divisia[1]	Time Trend		General Index	
			crs	vrs	crs	vrs
Div Isia		-	0.525***[2]	0.599***	0.979***	0.980***
Time Trend	crs	0.525***	-	0.824***	0.457***	0.459***
	vrs	0.599***	0.824***	-	0.566***	0.567***
General Index	crs	0.979***	0.457***	0.566***	-	0.999***
	vrs	0.980***	0.459***	0.567***	0.999***	-

*,**,***: significance at 10, 5, and 1 % -level.
1: calculated based on observed values.
2: Spearmans rank correlation test was applied.

It became clear that there are significant positive correlations for all different pairs of tfp index rankings. However, it seems from the results here that the general index model delivers more accurate tfp rankings for both scale specifications compared to the time trends model. These empirical findings in a way confirm the results of previous studies concluding in a better performance of the general index model with respect to the prediction of total factor productivity growth (see Baltagi/Griffin 1988, Baltagi et al. 1995, Kumbhakar/Heshmati 1996, Kumbhakar/Lovell 2000, and Kumbhakar 2004). It can be expected that the gi model is designed to more accurately handle annual fluctuation in the data structure compared to the tt model.

6.2. Non-Neutrality and Substitution Elasticities

The outlined time trends as well as general index models have been built on the assumption that technical change in organic milk farming is non-neutral. Hence, we also estimated time varying and farm specific bias in technical change. Table 5 gives a summary of the individual values per model specification, time period and variable input.

Table 5. Bias in Technical Change

Period	2002 – 2003				2003 - 2004			
Model	Time Trend		General Index		Time Trend		General Index	
Spec. Input	crs	vrs	crs	vrs	crs	vrs	crs	vrs
Land	1.256***	0.177***	0.942***	0.175***	1.259***	0.192***	0.943***	0.189***
Labor	-1.816***	-3.664***	-2.225***	-3.623***	-1.814***	-5.791***	-1.223***	-5.728***
Materials	-0.259***	-1.809***	-0.258***	-1.792***	-0.204***	-1.520***	-0.201***	-1.497***
Cows	-1.811***	0.294***	-1.812***	0.295***	-3.172***	0.589***	-3.178***	0.588***

*,**,***: significance at 10, 5, and 1 % -level.

The results were found to be consistent over the two models chosen and suggest that an upward and/or downward movement of the production function due to technical change has been biased in favour of the usages of labor and materials with respect to the variable scale specifications and in favour of labor, materials and cows for the constant returns to scale specifications. This holds for both time periods investigated. In other words these results imply that at average technical change on the organic farm level - if a positive rate could be actually achieved – has been labor, materials and cows saving.

The estimated output elasticities for the variable inputs show only minor changes over the years observed. Over all different model specifications marginal changes in the input materials lead to the highest output changes, marginal changes in the number of cows lead to the lowest output changes. This suggests that by using additional units of materials the organic milk farms can increase their milk output by a larger amount than by using additional units of cows (see table 6).

Table 6. Input Elasticities

Model	Time Trend					
Spec.	crs			vrs		
Input	2002	2003	2004	2002	2003	2004
Land	0.260***	0.261***	0.259***	0.309***	0.308***	0.306***
Labor	0.348***	0.344***	0.346***	0.213***	0.210***	0.213***
Materials	0.394***	0.394***	0.395***	0.551***	0.552***	0.552***
Cows	0.079***	0.080***	0.079***	0.128***	0.127***	0.127***
Model	General Index					
Spec.	crs			vrs		
Input	2002	2003	2004	2002	2003	2004
Land	0.312***	0.311***	0.310***	0.274***	0.272***	0.268***
Labor	0.288***	0.286***	0.287***	0.180***	0.177***	0.179***
Materials	0.401***	0.402***	0.403***	0.628***	0.626***	0.625***
Cows	0.062***	0.062***	0.061***	0.095***	0.094***	0.095***

*,**,***: significance at 10, 5, and 1 % -level.

Table 7 shows a taxonomy for the substitutional relationships between all inputs based on the estimated values for the Allen/Uzawa (AES) and Morishima (MES) elasticities of substition (see appendix A6a to A6d for numerical values). As expected by economic theory the own elasticities of substitution are negative implying an adherence to the law of diminishing marginal products.

The estimated AES for the constant returns specification are consistent for both models with respect to eight out of 13 pairs of inputs. The different models agree on a complementary relationship between land and materials as well as land and cows. On the other hand both result in substitutional relationships between land and labor as well as materials and cows. Here the highest values were found for the substitution elasticity between land and cows (-0.003 and -0.038 respectively). The estimated AES for the variable returns specification are consistent for both models with respect to 12 out of 13 pairs of inputs. The two models agree on a complementary relationship between land and labor as well as labor and materials and on a substitutional relationship between land and materials, land and cows, as well as materials and cows. The strongest relationship was again confirmed for land and cows (0.002 and 5.75E-04 respectively). All AES estimates showed to be consistent over time. As outlined before the Morishima elasticity of substitution is non symmetric by definition and so is the corresponding taxonomy of Morishima substitutes and complements. The estimated MES for the constant returns specification are consistent for both models with respect to 10 out of 13 pairs of inputs. The different models agree on a complementary relationship between land and materials, materials and land, materials and labor as well as cows and materials. On the other hand both result in substitutional relationships between land and cows, labor and cows, materials and labor, materials and cows, cows and land, as well as cows and labor. Here the highest values were found for the substitution elasticity between cows and materials as well as labor and cows (-1.40E-05 and 1.15E-03 respectively). The estimated MES for the variable returns specification are consistent for both models with respect to 12 out of 13 pairs of inputs. The two models agree on a complementary relationship between land and cows, labor and materials, materials and land, materials and labor as well as cows and materials and on the other hand on a substitutional relationship between land and labor, land and materials, labor and land, labor and cows, cows and land, as well as cows and labor. Here the strongest relationship was found for the substitution between labor and cows (3.81E-05 and 4.56E-05 respectively). All MES estimates showed to be consistent over time. Over all it can be concluded that for the constant returns specification the two measures revealed the same kind of relationship for seven out of 13 input pairs and for the variable returns specification for two out of 13 input pairs.

Table 7. Input Substitution Taxonomy for 2004

Model	Time Trend				General Index			
Spec.	crs				crs			
Input	Land[1]	Labor	Materials	Cows	Land[1]	Labor	Materials	Cows
Land	-	s/s	c/c	c/s	-	s/c	c/c	c/s
Labor	s/s	-	s/s	s/c	s/s	-	c/c	c/s
Materials	c/c	s/c	-	s/s	c/c	c/c	-	s/s
Cows	c/s	s/s	s/c	-	c/s	c/s	s/c	-
Spec.	vrs				vrs			
Input	Land	Labor	Materials	Cows	Land	Labor	Materials	Cows
Land	-	c/s	s/s	s/c	-	c/s	s/s	s/c
Labor	c/s	-	c/c	s/s	c/s	-	c/c	c/s
Materials	s/c	c/c	-	s/c	s/c	c/c	-	s/s
Cows	s/s	c/s	s/c	-	s/s	c/s	s/c	-

1: s – substitute, c – complement. 2: AES is symmetric, MES is non-symmetric.

6.3. Factors for Total Factor Productivity Growth

The estimated multiple equations systems delivered empirical evidence on factors potentially explaining the variance in total factor productivity growth of organic milk farms over the total period investigated. The results of the applied bias corrected bootstrap procedure confirmed the robustness of the SURE estimates (see appendix table A4).[12] Table 8 summarizes the most significant factors with respect to the development of total factor productivity over time for both models. We refer to the variable scale specifications here as the statistically superior ones (see LR-tests in table 2 and appendix A3).

Table 8. Most Significant Factors for TFP Change – VRS Specifications

Factor[1]	Influence on TFP Components by Factor Increase[2]	
Model	**Time Trend**	**General Index**
Total Investment	positive TCH, increase in EffCH	positive TCH, increase in EffCH
Investment in Quota	positive TCH, increase in EffCH	negative TCH, increase in EffCH
Organic Subsidies	increase in EffCH	positive TCH, increase in EffCH
Veterinary Expenses	increase in EffCH	increase in EffCH
External Finance	negative TCH, decrease in EffCH	positive TCH, decrease in EffCH
Total External Income	positive TCH, increase in EffCH	negative TCH, increase in EffCH

1: complete table of estimates see appendix table A4

2: TCH – Technical Change, EffCH – Change in Efficiency.

The analysis showed that for both models an increase in total investment, an increasing amount of organic subsidies received as well as rising veterinary expenses are significantly linked to a positive rate of technical change and an increase in farms' efficiency over time. Whereas an economically motivated explanation seems to be evident with respect to total investment - i.e. rising technical change and technical efficiency by more current technology as e.g. robotic weeding, band-steaming or automatic milking - such an explanation seems not that evident for the factor organic subsidies as well as veterinary expenses. One argumentation for the effect of the latter could be that an increase in veterinary expenses reflects a higher care of herd health and willingness to conquer diseases leading to an enhanced efficiency of the input cows. However, with respect to an increase in organic subsidies one could argue that this implies a larger farm budget for technology investments and scale enhancements. The different multiple equation systems delivered on the other hand mixed evidence with respect to the effects of increasing quota investments, total external income as well as the amount of external finance by the individual organic farm. Whereas the model evidence tends towards positive technical change effects and an increase in efficiency for the first two, the empirical evidence for the effects of an increase in ex-

[12] The estimation results of the single equation Tobit models showed more or less the same parameter values but with a lower statistical significance.

ternal finance clearly tends to negative influences on the organic farms' total productivity development in the period investigated. Increasing investments in milk quota lead to the availability of more current technology and the realization of scale effects through an enhancement of production. An increase in the total amount of off farm income (incl. rents and transfer payments) should result in a softer budget constraint and hence an additional increase in technology investments. Finally an increase in external finance over time implies beside increasing investments also rising debt and interest payments as well as risk exposure.

6.4. Probability of Market Exit

The estimated bivariate probit models are finally aimed to give empirical insights in the structural dynamics of the organic farming sector in Denmark over the last years. Table 9 summarizes the effects found for the different policy relevant factors tested for their influence on the probability of organic market exit. The results of the applied bias corrected bootstrap procedure confirmed the robustness of the bivariate probit estimates (see appendix table A5).

Tabel 9. Factors for Increased Probability of Organic Market Exit

Dependent Variable	**Exit Proxy TFP**	**Exit Proxy Leverage**
Factor[2]	Influence on Probability of Organic Market Exit	
Total Investment	negative	(not significant at 10%-level)
Investment in Quota	positive	(not significant at 10%-level)
Organic Subsidies	negative	negative
Total External Income	negative	negative
Total Period Operated by Current Farmer	negative	negative

1: binary proxies 0 – low likelihood, 1 – high likelihood of exit
2: complete table of estimates see appendix table A5.

By approximating the likelihood of organic market exit by the two binary variables defined in [29] reflecting the relative level and development of the farms' total factor productivity and the farms' leverage ratio, we found significant evidence for the following relationships: a lower likelihood of market exit for organic milk farms showing a relatively high increase in total investment over the last years, showing an increase in the amount of organic subsidies received, and generating an increasing part of the total income by off farm activities. In addition: the longer the total time period the organic farm is operated by the current owner the lower is the risk of organic market exit found. However, on the other hand we found for the probit model that increasing the investment in additional milk quota could lead to an increase in the risk of exiting the organic milk market. As outlined in section 2 the Danish organic milk sector has been plagued by a structural overproduction in the last years. Following the politically motivated assumption that - despite such short term overproduction - agricultural policy should focus on the long term goal of sustainable growth in organic farming in Europe one can conclude that ongoing monetary support by the state and supranational authorities as well as the promotion of off farm income opportunities would offer most promising starting points for effective policy measures to stimulate long term growth in organic production. Following on the other hand the purely economically motivated assumption that a mid to long term organic market equilibrium should be achieved where organic supply matches organic demand one can conclude that such ongoing monetary production support is a waste of resources and that fiscal policy should focus on an adequate discouraging marginal taxation of off farm earnings.

7. Conclusions

In the preceeding analysis we attempted to measure the total factor productivity growth of organic milk production in Denmark. By using recent panel data we tried to add to the empirical literature on organic farming. By considering theoretical consistency of the estimation model as well as applying different models we tried to add to the more modelling oriented literature on productivity analysis. Furthermore possible factors for explaining the variation in the different productivity components over time were investigated and policy relevant characteristics of farms likely to exit the market were analyzed. We found significant differences in the organic farms' technical efficiencies and total factor productivities on a high level (hypothesis 1). The results, however, only partly confirmed hypothesis 2 assuming no significant total factor productivity growth over the last years and show even a slightly negative rate of technical change for organic milk production in Denmark. However, it seems that these empirical results are not strong enough to support the view of a profound stagnation in organic milk farming. Hence, the overall development of organic milk farming in recent years is better described as a phase of 'breathtaking'.

We further found evidence for a positive relationship between subsidy payments and increasing farm efficiency as well as technology improvements (hypothesis 3). This holds also with respect to off farm earnings. Moreover hypothesis 4 has been confirmed, expecting a negative effect of an increase in subsidy payments as well as an increase in off farm income over time on the likelihood of market exit. With respect to the relative superiority of the different modelling approaches evidence was found for a more accurate mapping of total factor productivity growth by the general index model (hypothesis 5). The farm rankings by the different productivity indezes estimated were nevertheless found to be significantly correlated.

With respect to future policy measures these findings suggest that if further growth in organic farming should be stimulated, ongoing monetary support is effective to keep farms in the business. In addition policy measures should be also focused on promoting alternative off farm income possibilities. The latter suggestion seems to gain even more importance if one keeps in mind that organic dairy farms in Europe are expected to face reduced prices in the next years as a result of the general EU reform. Needless to say that beside such supply oriented measures also demand oriented measures have to be pursued. Future research should focus on shedding empirical light on the long term developments in the market. However, this requires the availability of a larger panel data set than currently available.

References

Agarwal, R. (1997): Survival of firms over the product life cycle. *Southern Economic Journal*. 63: 571 – 584.

Audretsch, D. B. (1994): Business survival and the decision to exit. *Journal of Economics and Business*. 1: 125 – 137.

Audretsch, D. B. (1995): *Innovation and industry evolution*. MIT, Cambridge, Massachusetts.

Audretsch, D. B., P. Houweling, A. R. Thurik (2000): Firm survival in the Netherlands. *Review of Industrial Organisation*. 16: 1 – 11.

Audretsch, D. B., T. Mahmood (1994): The rate of hazard confronting new firms and plants in U.S. manufacturing. *Review of Industrial Organisation*. 9: 41 – 56.

Audretsch, D. B., T. Mahmood (1995): New firm survival: new results using a hazard function. *Review of Economics and Statistics*. 77: 97 – 103.

Baltagi, B. H., J. M. Griffin (1988): A general index of technical change. *Journal of Political Economy*. 96: 20 – 41.

Baltagi, B. H., J. M. Griffin, P. Rich (1995): Airline deregulation: the cost pieces of the puzzle. *International Economic Review*. 36: 245 – 258.

Baltagi, B. H., P. Rich (2003): Skill-Based technical change in U.S. manufacturing: a general index approach. IZA Discussion Paper, No. 841.

Barnett, W. A. (2004): *Functional Structure and Approximation in Econometrics*, Elsevier.

Battese, G. E., T. J. Coelli (1992): Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. *Journal of Productivity Analysis*. 3: 153 – 169.

Battese, G. E., T. J. Coelli (1995): A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*. 20: 325 – 332.

Blackorby, C., R. R. Russell (1981): The Morishima elasticity of substitution: symmetry, constancy, separability, and its relationship to the Hicks and Allen elasticities. *Review of Economic Studies*. 48: 147 – 158.

Blackorby, C., R. R. Russell (1989): Will the real elasticity of substitution please stand up? (A comparison of the Allen/Uzawa and Morishima elasticities). *American Economic Review*. 79: 882 – 888.

Capalbo, S. M. (1988): Measuring the components of aggregate productivity growth in U.S. agriculture. *Western Journal of Agricultural Economics*. 13: 53 – 62.

Chambers, R. G. (1988): *Applied Production Analysis: A Dual Approach*. Cambridge University Press, Cambridge.

Coelli, T., D. S. Prasado, G. E. Battese (1998): *An Introduction to Efficiency and Productivity Analysis*. Kluwer, Boston.

DAAS (2005): Automatic milking (AMS) reduces the income in many farms. Danish Agricultural Advisory Centre.

Desli, E., S. C. Ray, S. C. Kumbhakar (2003): A dynamic stochastic frontier production model with time-varying efficiency. *Applied Economics Letters*. 10: 623 – 626.

Dimara, E., D. Skuras, K. Tsekouras, D. Tzelepis (2003): Firm efficiency and survival. Paper presented at the 2nd Hellenic Workshop on Productivity and Efficiency Measurement. University of Patras, Greece.

Doi, N. (1999): The determinants of firm exit in Japanese manufacturing industries. *Small Business Economics*. 13: 331 – 337.

Dunne, T., M. J. Roberts (1991): Variation in producer turnover across U.S. manufacturing industries, in: Geroski, P. A., J. Schwalbach (eds.). *Entry and market contestability: an international comparison*. Blackwell: London: 187 – 203.

Efron, B. (1979): Bootstrap Methods: Another Look at the Jacknife. *Annals of Statistics* 7: 1 – 26.

Efron, B., R. J. Tibshirani (1993): *An Introduction to the Bootstrap*. Chapman & Hall, London, UK.

Faere, R., S. Grosskopf, M. Norris and Z. Zhang (1994): Productivity growth, technical progress, and efficiency changes in industrialised countries. *American Economic Review*. 84: 66 – 83.

Flaten, O., G. Lien (2005): Stochastic utility-efficient programming of organic dairy farms. Paper presented at the XIth Congress of the EAAE, Copenhagen, Denmark.

Folkmann, P. S., Poulsen, B. (1998): Produktionsmuligheder og økonomi på økologiske jordbrugsbedrifter. Danish Institute of Agricultural and Fisheries Economics. Report No. 100.

Fotopoulos, G., H. Louri (2000): Location and survival of new entry. *Small Business Economics*. 14: 311 – 321.

Fried, H. O., C. A. K. Lovell, S. S. Schmidt (1993): *The measurement of productive efficiency: techniques and applications*, Oxford University Press: New York.

Greene, W. H. (1993): The econometric approach to efficiency analysis, in: Fried, H. O., C. A. K. Lovell, S. S. Schmidt 1993. *The measurement of productive efficiency: techniques and applications*, Oxford University Press: New York.

Greene, W. H. (1996): Marginal effects in the bivariate probit model. Working Paper No. 96 – 11. Department of Economics. Stern School of Business. New York University.

Greene, W. H. (2000): *Econometric analysis*, 5. Ed., Prentice-Hall: Upper Sadle River.

Haering, A. M., S. Dabbert, J. Aurbacher, B. Bichler, C. Eichert, D. Gambelli, N. Lampkin, F. Offermann, S. Olmos, J. Tuson, R. Zanoli (2004): *Organic farming and measures of European agricultural policy*. Organic farming in Europe: Economics and Policy. Vol. 11. Germany.

Hicks, J. R. (1932): *Theory of Wages*. London.

Horowitz, J. L. (2001): The Bootstrap. In: Heckman, J. J., E. Leamer (eds.). Handbook of Econometrics, Vol. 5, 3159 – 3228, Amsterdam: North-Holland.

Huang, C. J., J.-T. Liu (1994): Estimation of a non-neutral stochastic frontier production function. *Journal of Productivity Analysis*. 5: 171 – 180.

Jacobsen, B. H., N. Madsen, J. E. Ørum (2005): Organic farming at the farm level – Scenarios for the future development. KVL, Report No. 178.

Jánský, J., I. Zivelova, P. Novak (2003): Economic efficiency of agricultural enterprises in the system of organic farming. *Czech Agricultural Economics*. 49: 242 – 246.

Jorgenson, D. W., B. M. Fraumeni (1981): Relative prices and technical change. In.: Berndt, E. R. (eds.) Modelling and measuring natural resource substitution. MIT Press, Cambridge: 17 – 47.

Kledal, P. R. (2000): Økologiske jordbrug for fremtiden? – en økonomisk analyse af potentielle økologiske bedrifter. Working Paper No. 8/2000. Danish Institute of Agricultural and Fisheries Economics.

Klonsky, K., M. D., Smith (2002): Entry and Exit in California's organic farming sector. *Economics of Pesticides, Sustainable Food Production, and Organic Food Markets*. 4: 139 – 155.

Kompas, T., T. N., Che (2006): Technology choice and efficiency on Australian dairy farms. *The Australien Journal of Agricultural and Resource Economics*. 50: 65 – 83.

Kumbhakar, S. C. (1990): Production frontiers, panel data, and time-varying technical inefficiency. *Journal of Econometrics*. 46: 201 – 212.

Kumbhakar, S. C. (2004): Productivity and technical change: measurement and testing. *Empirical Economics*. 29: 185 – 191.

Kumbhakar, S. C., A. Heshmati (1996): Technical change and total factor productivity growth in Swedish manufacturing industries. *Econometric Reviews* 15: 275 – 298.

Kumbhakar, S. C., C. A. Knox Lovell (2000): *Stochastic frontier analysis*. Cambridge University Press: New York.

Kumbhakar, S. C., S. Ghosh, T. McGuckin (1991): A generalized production frontier approach for estimating determinants of inefficiency in U.S. dairy farms. *Journal of Business Economics and Statistics*: 279 – 286.

Kumbhakar, S. C., S. Nakamura, A. Hehmati (2000): Estimation of firm-specific technological bias, technical change and total factor productivity growth: a dual approach. *Econometric Reviews*. 19: 493 – 515.

KVL (2005): Regnskabsstatistik for økologisk jordbrug 2004. Serie G, No. 9, Fødevareøkonomisk Institut.

Lampkin, N., S. Padel (eds.) (1999): The Economics of Organic Farming. An International Perspective. CAB International: Wallingford/UK.

Lee, Y. H., P. Schmidt (1993): A production frontier model with flexible temporal-variation in technical inefficiency, In: Fried, H. O., C. A. K. Lovell, S. S. Schmidt 1993. *The measurement of productive efficiency: techniques and applications*, Oxford University Press: New York.

Lohr, L., L. Salomonsson (2000): Conversion subsidies for organic production: results from Sweden and lessons for the United States. *Agricultural Economics*. 22: 133 – 146.

Luh, Y., S. Stefanou (1993): Learning-by-doing and the sources of productivity growth: a dynamic model with application to U.S. agriculture. *Journal of Productivity Analysis*. 4: 353 – 370.

Madau, F. A. (2005): Technical efficiency in organic farming: an application on Italian cereal farms using a parametric approach. Paper presented at the XIth Congress of the EAAE, Copenhagen, Denmark.

Mahmood, T. (2000): Survival of newly founded businesses: a log-logistic model approach. *Small Business Economics*. 14: 223 – 237.

Mayer, W. J., W. F. Chappel (1992): Determinants of entry and exit: an application of the compounded bivariate Poisson distribution to U.S. industries. *Southern Economic Journal*. 58: 770 – 778.

Nieberg, H., F. Offermann, K. Zander, P. Jægersberg (2005): Further development of organic farming policy in Europe. Draft Report. FAL. Germany.

Nishimizu, M., J. M. Page Jr. (1982): Total factor productivity growth, technological progress and technical efficiency change: dimensions of productivity change in Yugoslavia, 1965 – 78. *The Economic Journal*. 92: 920 – 936.

Norfelt, T. F. (2005): Organic farming in Denmark – 2005. Dansk Landbrugsrådgivning Landscentret. 22/12/2005.

Offermann, F., H. Nieberg (2002): Does organic farming have a future in Europe? *EuroChoices* 1: 12 – 17.

Oude Lansink, A., K. S. Pietola, S. Bæckman (2002): Efficiency and productivity of conventional and organic farms in Finland 1994 – 1997. *European Review of Agricultural Economics*. 29: 51 – 65.

Pietola, K. S., A. O. Lansink (2001): Farmer response to policies promoting organic farming technologies in Finland. *European Review of Agricultural Economics*. 28: 1 – 15.

Rainelli, P., D. Vermersch (2000): Comparing the profitability of organic and conventional farming: the impact of support on arable farming in France. OECD Working Paper, Vol. 8, No. 22.

Ryan, D. L., T. J. Wales (2000): Imposing Local Concavity in the Translog and Generalized Leontief Cost Functions. *Economic Letters*. 67: 253 – 260.

Sauer, J. (2006): Economic Theory and Econometric Practice: Parametric Efficiency Analysis. *Empirical Economics*. 7/2006 online.

Segarra, A., M. Callejón (2002): New firms' survival and market turbulene: new evidence from Spain. *Review of Industrial Organisation*. 20: 1 – 14.

Sipilæinen, T., A. Oude Lansink (2005): Learning in organic farming – an application on Finnish dairy farms. Paper presented at the XIth Congress of the EAAE, Copenhagen, Denmark.

DPD/The Danish Plant Directorate (2004): Statistik over økologiske jordbrugsbedrifter 2003. Juni 2004.

The Organic Council (1999): Aktionsplan II – Økologi I udvikling. Det Økologiske Fødevareråd.

Thompson, H. (1997): Substitution elasticities with many inputs. *Applied Mathematical Letters*. 10: 123 – 127.

Tsionas, E. G., T. A. Papadogonas (2005): Firm exit and technical inefficiency. *Empirical Economics*. 2005 online.

Tvedegaard. N. (2000): Conversion to organic crop production – an analysis of the economic consequences at selected farms. Working Paper No. 2/2000. Danish Institute of Agricultural and Fisheries Economics (Danish).

Tvedegaard. N. (2002): Organic milk production – economic analyses. Report No. 137. Danish Institute of Agricultural and Fisheries Economics (Danish).

Tvedegaard. N. (2005): Organic pig production. Report No. 174. Danish Institute of Agricultural and Fisheries Economics (Danish).

Tzouvelekas, V., C. J. Pantzios, C. Fotopoulos (2001a): Technical efficiency of alternative farming systems: the case of Greek organic and conventional olive-growing farms. *Food Policy*. 26: 549 – 569.

Tzouvelekas, V., C. J. Pantzios, C. Fotopoulos (2001b): Economic efficiency in organic farming: evidence from cotton farms in Viotia, Greece. *Journal of Agricultural & Applied Economics*. 33: 35 – 48.

Tzouvelekas, V., C. J. Pantzios, C. Fotopoulos (2002): Empirical evidence of technical efficiency levels in Greek organic and conventional farms. *Agricultural Economics Review*. 3: 49 – 60.

Wagner, J. (1994): Small firm entry in manufacturing industries. *Small Business Economics*. 5: 211 – 214.

Wheelock, D. C., P. W. Wilson (1995): Explaining bank failures: deposit insurance, regulation, and efficiency. *Review of Economics and Statistics*. 77: 689 – 700.

Wooldridge, J. M. (2002): *Econometric analysis of cross section and panel data*. MA: MIT Press. Cambridge.

Wynen, E. (1998): Organic agriculture in Denmark – economic impacts of a widespread adoptation of organic management. Report No. 99. Danish Institute of Agricultural and Fisheries Economics.

Zhengfei, G., A. Oude Lansink, A. Wossink, R. Huirne (2005): Damage Control Inputs: A Comparison of Conventional and Organic Farming Systems, European Review of Agricultural Economics. 52: 167 – 189.

Appendix

Table A1. Descriptive Statistics – Full Sample

Variable	mean	stdev	min	max
Total Revenue ('000 DKK)	2,807.490	996,759.6	1,009,450	6,278,403
Total Milk Revenue ('000 DKK)	2,083.749	716,387.9	671,428	4,273,821
Labor (hours per year)	4,991.06	1,343.082	2,420	10,100
Cows (n)	103.762	35.129	31	223
Material (DKK)	521,898.6	284,946	57,832	2,096,858
Land (ha)	137.711	60.580	47.73	479
Capital (DKK)	1.29e+07	4,787,615	4,496,965	2.83e+07
Investments (DKK)	1,279,805	2,108,576	0	1.31e+07
Investment in Milk Quota (DKK)	177,538.8	351,621.6	0	2,589,105
Organic Subsidies (DKK)	84,860.21	51,735.8	21,228	383,345
Veterinary Expenses (DKK)	54,636.72	31,070.66	0	185,499
External Finance (DKK)	1,126,260	2,066,524	0	1.27e+07
Total External Income (DKK)	102,039.5	39,871.06	6,095.3	248,075.1
Leverage Ratio (Debt/Total Assets in %)	65.15	16.65	16.07	96.94
Farm Location (1: Jutland, 0: Sealand, Fynen)	0.946	0.226	0	1
Age of Farmer (years)	46	6.856	33	61
Years Farmer is Operating the Farm (n)	20.375	7.403	6	36

1: 56 observations per year, 168 observations in total.
2: base year 2002.
3: 1 DKK = 0.135 Euro (31.12.2002).
4: producer price index for agricultural materials p.a. 2003: 102.48, 2004: 109.64; general inflation % p.a. 2003: 2.1, 2004: 1.2; price index for milk and dairy products p.a. 2003: 104.95, 2004: 105.29; price index for machinery p.a. 2003: 96.39, 2004: 92.42 (sources: OECD, Danmark Statistic).

Table A2. Estimates Time Trend Specification – Error Components Frontier Model

CRS - Specification

PARAMETER	ESTIMATE	STERR	PARAMETER	ESTIMATE	STERR
β_0	0.807	0.001***	β_{labl}	0.265	0.259
β_{lab}	1.676	0.588***	β_{cm}	-3.069	0.532***
β_{cows}	0.984	0.534**	β_{cl}	-1.539	0.424***
β_{mat}	-1.442	0.278***	β_{ml}	0.994	0.379***
β_{land}	-0.218	0.151*	ς_{cap}	0.251	0.054***
β_{lablab}	-1.662	0.588***	χ_t	-0.012	0.005***
β_{cc}	1.439	0.292***	χ_{tt}	-0.003	0.001***
β_{mm}	1.557	0.278***	δ_{labt}	-0.011	0.002***
β_{ll}	0.279	0.143**	δ_{ct}	-0.016	0.021
β_{labc}	0.878	0.793	δ_{mt}	0.023	0.025
β_{labm}	0.518	0.237**	δ_{lt}	0.004	0.001***
μ	0.702	0.107***			
η	0.012	0.008*			
σ^2	4.82E-05	9.49E-06**			
γ_t	0.666	0.0781***			
σ_u^2	3.21E-05	9.62E-06**			
σ_v^2	1.61E-05	2.23E-06***			
γ_{inv}	-4.91E-07	2.55E-07**	γ_{qu}	-4.23E-07	8.33E-07
γ_{orgs}	4.98E-06	4.48E-06	γ_{vet}	2.14E-06	5.29E-06
γ_{extfin}	3.06E-07	2.44E-07	$\gamma_{extinctot}$	-3.80E-07	5.70E-07
$\gamma_{extincfam}$	4.12E-06	1.98E-06***	γ_{reg}	0.0544	0.805
γ_0	-9.355	0.197***			
WALDCHI^2(16)	7901.42				
LL	633.713		BORDERED PRINCIPAL MINORS (SAMPLE MEAN)[1]		
P>CHI^2	0.000		bpm1 = -0.067	bpm2 = 0.064	bpm3 = -0.009
MONOTONICITY (%)	100		bpm4= 5.22E-04		
SAMPLE SIZE	N = 168		QUASI-CONCAVITY (%) = 100		

*,**,***: significance at 10, 5, and 1 % -level.; 1: calculated for every observation.

VRS - Specification					
PARAMETER	**ESTIMATE**	**STERR**	**PARAMETER**	**ESTIMATE**	**STERR**
β_0	1.216	0.348***	β_{labl}	0.161	0.484
β_{lab}	-0.284	0.138*	β_{cm}	-3.011	0.572***
β_{cows}	1.158	0.739*	β_{cl}	-1.537	0.424***
β_{mat}	-1.409	0.843**	β_{ml}	1.015	0.433***
β_{land}	-0.139	0.039***	ς_{cap}	0.260	0.053***
β_{lablab}	-0.401	0.959	χ_t	-0.062	0.043*
β_{cc}	1.453	0.287***	χ_{tt}	2.55E-04	2.26E-05***
β_{mm}	1.612	0.289***	δ_{labt}	0.041	0.004***
β_{ll}	0.277	0.176*	δ_{ct}	-0.032	0.024*
β_{labc}	0.626	0.891	δ_{mt}	0.039	0.031*
β_{labm}	0.284	0.902	δ_{lt}	0.005	0.001***
μ	0.273	0.063***			
η	0.019	0.008**			
σ^2	4.67E-05	9.02E-06***			
γ_t	0.672	0.077***			
σ_u^2	3.14E-05	9.17E-06***			
σ_v^2	2.53E-05	2.16E-06***			
γ_{inv}	-1.84E-07	1.98E-07	γ_{qu}	1.94E-07	3.68E-07
γ_{orgs}	-5.19E-07	3.99E-06	γ_{vet}	-4.11E-06	5.31E-06
γ_{extfin}	1.12E-07	1.69E-07	$\gamma_{extinctot}$	-1.50E-06	6.36E-07***
$\gamma_{extincfam}$	3.33E-06	1.69E-06**	γ_{reg}	0.479	0.777
γ_0	-7.703	0.639***			
WALDCHI^2(16)	885.61				
LL	636.922		BORDERED PRINCIPAL MINORS (SAMPLE MEAN)[1]		
P>CHI^2	0.000		bpm1 = -0.043	bpm2 = 0.009	
MONOTONICITY (%)	100		bpm3 = -6.64E-04	bpm4= 9.38E-05	
SAMPLE SIZE	N = 168		QUASI-CONCAVITY (%) = 100		

*,**,***: significance at 10, 5, and 1 % -level.; 1: calculated for every observation.

Table A3. Estimates General Index Specification

CRS – Specification / Production Function

PARAMETER	ESTIMATE	STERR	PARAMETER	ESTIMATE	STERR
β_0	5.547	0.416***	β_{labl}	0.139	0.011***
β_{lab}	2.751	0.049***	β_{cm}	-0.174	0.007***
β_{cows}	0.468	0.091***	β_{cl}	-0.149	0.006***
β_{mat}	-1.166	0.032***	β_{ml}	0.066	0.018***
β_{land}	-0.585	0.086***	ς_{cap}	0.165	0.025***
β_{lablab}	-0.257	0.006***	χ_t	-7.665	0.415***
β_{cc}	0.263	0.019***	χ_{tt}	28.814	0.415***
β_{mm}	0.051	0.002***	δ_{laba}	-0.146	0.049***
β_{ll}	-0.055	0.017***	δ_{ca}	-0.004	0.091
β_{labc}	0.061	0.011***	δ_{ma}	-0.048	0.032
β_{labm}	0.058	0.004***	δ_{la}	0.055	0.086
ϕ_{02}	0.002	0.003	ϕ_{03}	0.003	0.004
ϕ_{04}	-7.01E-04	-9.52E-04			
γ_{inv}	1.63E-05	3.52E-05	γ_{qu}	-1.14E-04	3.91E-05***
γ_{orgs}	-1.14E-03	4.16E-05***	γ_{vet}	6.27E-04	4.34E-05***
γ_{extfin}	1.19E-04	3.64E-05***	$\gamma_{extinctot}$	0.013	1.22E04***
$\gamma_{extincfam}$	1.70E-05	4.27E-05	γ_{reg}	-4.01E-04	4.81E-04
ADJR^2	0.848				
F-VALUE	28.124		BORDERED PRINCIPAL MINORS (SAMPLE MEAN)[1]		
P>F	0.000		bpm1 = -0.097	bpm2 = 0.054	
MONOTONICITY (%)	100		bpm3 = -0.008	bpm4= 3.48E-04	
SAMPLE SIZE	N = 168		QUASI-CONCAVITY (%) = 100		

*,**,***: significance at 10, 5, and 1 % -level.; 1: calculated for every observation.

CRS – Specification / TFP function

PARAMETER	ESTIMATE	STERR	PARAMETER	ESTIMATE	STERR
ϕ_{02}	-7.51E-04	0.025	δ_{laba}	0.262	0.015***
ϕ_{04}	-2.67E-05	0.002	δ_{ca}	-0.738	0.014***
ϕ_{03}	1.63E-04	0.024	δ_{ma}	-0.261	0.001***
χ_t	5.702	0.014***	δ_{la}	-0.372	0.144***
χ_{tt}	2.458	0.015***			
ADJR^2	0.875				
F-VALUE	28.124				
P>F	0.000				

*,**,***: significance at 10, 5, and 1 % -level.

VRS – Specification / Production Function

Parameter	Estimate	StErr	Parameter	Estimate	StErr
β_0	25.559	0.388***	β_{labl}	-0.129	0.005***
β_{lab}	-1.265	0.046***	β_{cm}	-0.669	0.006***
β_{cows}	4.720	0.085***	β_{cl}	-0.914	0.006***
β_{mat}	-3.257	0.0298***	β_{ml}	0.281	0.017***
β_{land}	-1.137	0.081***	ς_{cap}	0.209	0.023***
β_{lablab}	-0.1290	0.005***	χ_t	37.089	0.388***
β_{cc}	0.849	0.018***	χ_{tt}	-68.107	0.389***
β_{mm}	0.121	0.002***	δ_{laba}	-0.153	0.046***
β_{ll}	0.123	0.016***	δ_{ca}	0.693	0.085**
β_{labc}	0.041	0.009***	δ_{ma}	0.058	0.029***
β_{labm}	0.231	0.004***	δ_{la}	0.413	0.081***
ϕ_{02}	2.03E-04	0.672	ϕ_{03}	-2.01E-04	0.673
ϕ_{04}	5.12E-04	0.670			
γ_{inv}	3.23E-05	2.087E-05	γ_{qu}	-3.71E-05	2.31E-05
γ_{orgs}	-5.35E-04	2.466E-05	γ_{vet}	2.53E-04	2.57E-05***
γ_{extfin}	-4.71E-05	2.15E-05**	$\gamma_{extinctot}$	-9.33E-05	2.53E-05***
$\gamma_{extincfam}$	4.52E-03	7.23E-05***	γ_{reg}	-0.001	2.84E-04***
AdjR^2	0.837				
F-value	31.827		Bordered Principal Minors (sample mean)[1]		
p>F	0.008		bpm1 = -0.034	bpm2 = 0.006	
monotonicity (%)	100		bpm3 = -4.92E-04	bpm4= 8.81E-05	
sample size	N = 168		quasi-concavity (%) = 100		

*,**,***: significance at 10, 5, and 1 % -level.; 1: calculated for every observation.

VRS – Specification / TFP function

Parameter	Estimate	StErr	Parameter	Estimate	StErr
ϕ_{02}	-5.49E-05	0.005	δ_{laba}	0.076	0.003***
ϕ_{04}	-4.94E-05	0.004	δ_{ca}	-0.426	0.002***
ϕ_{03}	4.52E-05	0.004	δ_{ma}	-0.355	0.003***
χ_t	13.888	0.003***	δ_{la}	0.006	0.002***
χ_{tt}	1.864	0.002***			
AdjR^2	0.884				
F-value	32.144				
p>F	0.002				

*,**,***: significance at 10, 5, and 1 % -level.

Table A4. Bias-Corrected Bootstrapped Estimates Multiple Equations System

Equation	Technical Change			Efficiency Change			Scale Efficiency Change		
Parameter	Estimate	StErr	Bias Corrected Conf. Interval	Estimate	StErr	Bias Corrected Conf. Interval	Estimate	StErr	Bias Corrected Conf. Interval
TT Model – VRS Specification									
κ_{inv}	0.973	0.002***	[0.968; 0.977]	1.006	0.004***	[0.997; 1.014]	1.005	0.003***	[1.001; 1.011]
κ_{quota}	1.30E-09	8.64E-10*	[-6.02E-10; 2.63E-09]	6.65E-09	1.57E-09***	[3.11E-09; 9.80E-09]	1.25E-09	1.03E-09	[-3.51E-10; 3.43E-09]
κ_{orgs}	-2.09E-07	1.68E-07	[-6.29E-07; 2.45E-07]	7.21E-07	3.07E-07***	[2.99E-07; 1.31E-06]	4.03E-07	2.01E-07**	[1.60E-07; 1.05E-06]
κ_{vet}	1.27E-08	1.53E-08	[-1.53E-08; 4.96E-08]	5.59E-08	2.78E-08**	[-2.84E-08; 1.34E-07]	-1.14E-08	1.83E-08	[-9.65E-08; 2.75E-08]
κ_{extfin}	-9.09E-09	4.31E-09**	[-1.79E-08; -3.06E-09]	-4.26E-08	7.84E-09***	[-6.30E-08; -1.01E-08]	-3.66E-09	5.15E-09	[-1.35E-08; 3.42E-09]
κ_{exincf}	-1.34E-07	1.33E-07	[-7.17E-07; 1.62E-07]	-1.43E-07	2.43E-07	[-4.95E-07; 3.75E-07]	-5.41E-08	1.60E-07	[-2.99E-07; 1.47E-07]
$\kappa_{exincfam}$	-4.04E-08	5.89E-08	[-1.60E-07; 1.00E-07]	-1.84E-07	1.07E-07*	[-4.16E-07; 2.78E-08]	2.98E-08	7.04E-08	[-9.68E-08; 2.13E-07]
$\kappa_{exinctot}$	1.67E-08	7.56E-09***	[3.65E-09; 3.55E-08]	7.88E-08	1.38E-08***	[4.72E-08; 1.23E-07]	3.21E-08	9.03E-09***	[1.30E-08; 5.97E-08]
R^2	0.118			0.475			0.194		
Chi^2	2.05E05***		6.64E04***			1.53E05***			N = 112
Replications	1000			1000			1000		(*,**,***: significance at 10, 5, and 1 % -level)
GI Model – VRS Specification									
κ_{inv}	0.999	2.81E-05***	[0.998; 0.999]	1.039	0.007***	[1.026; 1.052]	1.002	3.75E-04	[0.677; 1.003]
κ_{quota}	-1.86E-11	1.09E-11**	[-3.36E-11; 2.82E-12]	1.64E-08	2.77E-09***	[6.26E-09; 2.75E-08]	-1.45E-10	1.46E-10	[-5.17E-10; 2.17E-10]
κ_{orgs}	3.92E-09	2.13E-09**	[-7.24E-10; 7.37E-09]	1.48E-06	5.40E-07***	[7.19E-07; 3.88E-06]	3.38E-08	2.84E-08	[-1.73E-08; 7.20E-08]
κ_{vet}	-2.23E-10	1.93E-10	[-6.31E-10; 1.20E-10]	4.05E-07	4.90E-08***	[2.79E-07; 5.96E-07]	2.84E-10	2.58E-09	[-7.98E-09; 7.26E-09]
κ_{extfin}	7.84E-11	5.45E-11*	[-1.12E-11; 1.70E-10]	-5.02E-08	1.38E-08***	[-1.03E-07; 2.56E-08]	5.34E-10	7.26E-10	[-2.11E-09; 2.80E-09]
κ_{exincf}	1.71E-09	1.69E-09	[-1.83E-09; 5.61E-09]	1.13E-07	4.28E-07	[-7.20E-07; 1.21E-06]	9.33E-09	2.25E-08	[-3.26E-08; 6.69E-08]
$\kappa_{exincfam}$	2.64E-10	7.45E-10	[-1.62E-09; 2.00E-09]	-1.70E-07	1.89E-07	[-5.40E-07; 1.78E-07]	-7.69E-10	9.93E-09	[-2.36E.08; 2.18E-08]
$\kappa_{exinctot}$	-2.89E-10	9.56E-11***	[-4.51E-10; -1.05E-10]	2.68E-07	2.42E-08***	[2.09E-07; 3.62E-07]	2.35E-09	1.27E-08**	[-1.61E-09; 5.53E-09]
R^2	0.149		0.706			0.058			
Chi^2	1.28E09***		2.34E04***			7.29E06***			N = 112
Replications	1000			1000			1000		(*,**,***: significance at 10, 5, and 1 % -level)

Table A5. Bias-Corrected Bootstrapped Estimates Bivariate Probit Model

EQUATION	EXIT PROXY 1 (TFP)			EXIT PROXY 2 (LEVERAGE)		
PARAMETER	ESTIMATE	STERR	BIAS CORRECTED CONF. INTERVAL	ESTIMATE	STERR	BIAS CORRECTED CONF. INTERVAL
ζ_{inv}	-4.13E-07	2.41E-07**	[-1.01E-06; 6.79E-07]	1.56E-07	1.69E-07	[-4.82E-06; 2.31E-05]
ζ_{quota}	1.35E-06	6.20E-07***	[-1.31E-06; 5.12E-06	-1.90E-07	5.79E-07	[-2.31E-05; 3.94E-05]
ζ_{orgs}	-8.55E-06	4.79E-06**	[-3.18E05; 4.47E-06]	-8.34E-06	5.52E-06*	[-5.82E-04; 3.73E-05]
ζ_{extfin}	2.25E-07	2.17E-07	[-8.11E-07; 7.53E-07]	8.72E-08	1.63E-07	[-2.27E-05; 2.62E-06]
ζ_{scale}	-3.92E-08	1.35E-07	[-6.71E-07; 4.53E-07]	1.58E-07	1.77E-07	[-1.76E-05; 3.75E-06]
ζ_{exincf}	-2.12E-06	1.14E-05	[-4.39E-05; 9.59E-05]	-4.29E-06	1.24E-05	[-2.99E-04; 7.01E-04]
$\zeta_{exincfam}$	-1.79E-06	4.51E-06	[-1.97E-05; 1.17E-05]	-1.79E-06	4.19E-06	[-7.96E-04; -1.22E-04]
$\zeta_{exinctot}$	-1.28E-06	7.33E-07**	[-4.14E-06; 1.53E-06]	-8.69E-07	7.75E-08**	[-4.08E-06; 2.58E-04]
$\zeta_{køb}$	-0.044	0.029**	[-0.124; 0.067]	-0.056	0.032**	[-0.138; 4.031]
ζ_{0}	0.782	0.647	[-1.362; 2.378]	0.241	0.636	[-35.403; 4.268]
ρ						
LL	-51.623					
Chi^2	37.67***					
Replications	1000		N = 56			

(*,**,***: significance at 10, 5, and 1 % -level)

Table A6a. Input Substitution TT CRS – Allen/Uzawa Elasticities and Morishima Elasticities (Inverse)

Model		Time Trend		
Spec. Input		crs		
Period		**2002**		
	Land[1]	Labor	Materials	Cows
Land	-2.65E-04**	2.01E-04** / *6.19E-06****	-4.34E-07*** / *-5.85E-06****	-0.003** / *3.92E-06**
Labor	2.01E-04** / *5.83E-06****	-4.66E-06***	1.89E-08** / *2.92E-06****	4.72E-05*** / *-3.30E-05****
Materials	-4.34E-07*** / *-4.45E-06***	1.89E-08** / *-2.02E-06**	-4.74E-06***	7.85E-07*** / *7.32E-05****
Cows	-0.003** / *3.74E-07**	4.72E-05*** / *3.17E-06***	7.85E-07*** / *-1.57E-05***	-0.002**
Period		**2003**		
	Land	Labor	Materials	Cows
Land	-2.94E-04*	2.26E-04** / *6.40E-06****	-3.88E-07** / *-5.71E-06****	-0.002** / *2.53E-06*
Labor	2.26E-04** / *5.54E-06****	-5.07E-06***	1.98E-08* / *3.16E-06***	4.70E-05*** / *-3.14E-05****
Materials	-3.88E-07** / *-3.83E-06***	1.98E-08* / *-2.18E-06**	-4.79E-06***	7.73E-07*** / *7.02E-05****
Cows	-0.002** / *2.68E-07*	4.70E-05*** / *3.47E-06**	7.73E-07*** / *-1.48E-05***	-0.002*
Period		**2004**		
	Land	Labor	Materials	Cows
Land	-2.71E-04*	2.08E-04** / *5.43E-06****	-3.82E-07** / *-5.35E-06***	-0.003** / *3.59E-06*
Labor	2.08E-04** / *5.53E-06***	-4.62E-06**	2.11E-08* / *3.15E-06**	4.55E-05*** / *-3.13E-05***
Materials	-3.82E-07** / *-3.93E-06**	2.11E-08* / *-1.99E-06***	-4.43E-06***	7.52E-07*** / *6.82E-05****
Cows	-0.003** / *3.22E-07*	4.55E-05*** / *3.12E-06***	7.52E-07*** / *-1.40E-05***	-0.002**

1: value of AES / value of MES; *,**,***: significance at 10, 5, and 1 % -level,

Table A6b. Input Substitution TT VRS – Allen/Uzawa Elasticities and Morishima Elasticities (Inverse)

Model	Time Trend			
Spec. Input	vrs			
Period	2002			
	Land[1]	Labor	Materials	Cows
Land	-3.71E-04*	-3.44E-05* / *4.98E-06***	4.28E-07** / *4.95E-06***	0.003** / *-3.80E-06*
Labor	-3.44E-05* / *2.14E-06***	-6.46E-08***	-2.85E-08* / *-4.14E-06***	-3.16E-04* / *5.18E-05***
Materials	4.28E-07** / *-3.44E-06***	-2.85E-08* / *-4.98E-06****	-3.63E-06***	3.85E-07** / *3.91E-05***
Cows	0.003** / *3.70E-07**	-3.16E-04* / *3.64E-05**	3.85E-07** / *-5.24E-06****	-4.13E-04**
Period	2003			
	Land	Labor	Materials	Cows
Land	-2.83E-04*	-2.77E-05* / *4.36E-06***	3.45E-07* / *1.84E-05*	0.002* / *-2.03E-06****
Labor	-2.77E-05* / *1.90E-06**	-5.37E-08***	-2.90E-08* / *-4.50E-06*	-3.38E-04* / *4.01E-05***
Materials	3.45E-07 */ *-3.38E-06***	-2.90E-08* / *-4.47E-06****	-3.47E-06*	3.88E-07* / *3.50E-05**
Cows	0.002* / *3.78E-07**	-3.38E-04* / *1.45E-05*	3.88E-07* / *-4.30E-06****	-3.39E-04**
Period	2004			
	Land	Labor	Materials	Cows
Land	-2.51E-04	-2.60E-05** / *4.60E-06***	3.45E-07* / *3.87E-06**	0.002* / *-2.51E-06****
Labor	-2.60E-05** / *2.20E-06***	-4.84E-09***	-3.51E-08** / *-4.40E-06**	-2.40E-04*** / *3.81E-05***
Materials	3.45E-07* / *-3.31E-06***	-3.51E-08** / *-4.15E-06****	-3.27E-06***	4.25E-07* / *4.29E-05**
Cows	0.002* / *4.56E-07***	-2.40E-04*** / *6.02E-06****	4.25E-07* / *-4.10E-06**	-4.42E-04*

1: value of AES / value of MES; *,**,***: significance at 10, 5, and 1 % -level,

Table A6c. Input Substitution GI CRS – Allen/Uzawa Elasticities and Morishima Elasticities (Inverse)

Model	General Index			
Spec. Input	crs			
Period	2002			
	Land[1]	Labor	Materials	Cows
Land	-0.014	3.94E-03** / *-3.02E-03****	-1.26E-05** / *-2.09E-04****	-0.038* / *5.02E-05*
Labor	3.94E-03** / *1.22E-03****	-7.42E-04***	-8.12E-07*** / *-1.71E-04****	-2.35E-03** / *1.11E-03****
Materials	-1.26E-05** / *-5.90E-04****	-8.12E-07*** / *-1.21E-03****	-3.69E-05***	2.92E-06*** / *2.03E-04****
Cows	-0.038* / *2.73E-05*	-2.35E-03** / *1.67E-03****	2.92E-06*** / *-4.36E-05****	-0.005***
Period	2003			
	Land	Labor	Materials	Cows
Land	-0.015	4.12E-03* / *-3.05E-03****	-1.32E-05** / *-2.18E-04****	-0.037* / *4.11E-05*
Labor	4.12E-03* / *1.21E-03****	-7.65E-04***	-8.73E-07*** / *-1.81E-04****	-2.35E-03** / *1.07E-03****
Materials	-1.32E-05** / *-5.94E-04****	-8.73E-07*** / *-1.26E-03****	-3.97E-05***	3.00E-06*** / *2.01E-04****
Cows	-0.037* / *2.26E-05*	-2.35E-03** / *1.66E-03****	3.00E-06*** / *-4.25E-05****	-0.004***
Period	2004			
	Land	Labor	Materials	Cows
Land	-0.013	4.11E-03* / *-3.05E-03****	-1.28E-05*** / *-2.13E-04****	-0.038 / *5.77E-05*
Labor	4.11E-03* / *1.20E-03****	-7.89E-04***	-8.89E-07*** / *-1.82E-04****	-2.59E-03* / *1.15E-03****
Materials	-1.28E-05*** / *-5.86E-04****	-8.89E-07*** / *-1.29E-03****	-3.86E-05***	3.05E-06*** / *2.10E-04****
Cows	-0.037* / *3.06E-05*	-2.59E-03* / *1.74E-03****	3.05E-06*** / *-4.51E-05****	-0.005**

1: value of AES / value of MES; *,**,***: significance at 10, 5, and 1 % -level,

Table A6d. Input Substitution GI VRS – Allen/Uzawa Elasticities and Morishima Elasticities (Inverse)

Model	General Index			
Spec. Input	vrs			
Period	2002			
	Land[1]	Labor	Materials	Cows
Land	-4.05E-04	-2.55E-05* / *2.68E-06***	3.38E-07* / *4.51E-06***	6.52E-04*** / *-2.79E-06****
Labor	-2.55E-05* / *1.79E-06***	-2.11E-08**	-2.58E-08* / *-2.42E-06*	-4.20E-05** / *4.24E-05**
Materials	3.38E-07* / *-3.81E-06***	-2.58E-08* / *-3.38E-06**	-3.18E-06*	3.82E-07* / *4.50E-05***
Cows	6.52E-04*** / *2.87E-07****	-4.20E-05** / *5.23E-06***	3.82E-07* / *-5.66E-06*	-3.23E-04***
Period	2003			
	Land	Labor	Materials	Cows
Land	-2.97E-04*	-2.71E-05 / *2.50E-06***	3.48E-07* / *4.23E-06***	6.53E-04*** / *-2.24E-06***
Labor	-2.71E-05 / *1.92E-06***	-2.41E-08***	-2.55E-08* / *-2.01E-06****	-3.88E-05*** / *3.80E-05**
Materials	3.48E-07* / *-3.88E-06***	-2.55E-08* / *-3.06E-06**	-3.00E-06**	3.99E-07* / *3.93E-04**
Cows	6.53E-04*** / *2.78E-07****	-3.88E-05*** / *4.59E-06***	3.99E-07* / *-4.66E-06***	-2.89E-04**
Period	2004			
	Land	Labor	Materials	Cows
Land	-3.15E-04*	-2.00E-05* / *2.57E-06****	3.58E-07* / *4.25E-06***	5.75E-04*** / *-2.43E-06**
Labor	-2.00E-05* / *1.87E-06****	-2.13E-08*	-2.21E-08* / *-2.40E-06****	-4.91E-05*** / *4.56E-05**
Materials	3.58E-07* / *-3.91E-06***	-2.21E-08* / *-3.13E-06***	-2.90E-06*	4.33E-07* / *4.58E-05**
Cows	5.75E-04*** / *2.70E-07***	-4.91E-05*** / *5.10E-06***	4.33E-07* / *-4.77E-06***	-2.92E-04***

1: value of AES / value of MES; *,**,***: significance at 10, 5, and 1 % -level,

Working Papers

Fødevareøkonomisk Institut

08/06	August 2006	Johannes Sauer, Jesper Graversen, Tim Park, Solange Sotelo, Niels Tvedegaard	Recent Productivity Developments and Technical Change in Danish Organic Farming – Stagnation?
07/06	Maj 2006	Johannes Sauer	Prices and Species Deversity – Stochastic Modelling of Environmental Efficiency
06/06	Maj 2006	Jacob Ladenburg Søren Bøye Olsen	Starting Point Anchoring Effects in Choice Experiments
05/06	Marts 2006	Svend Rasmussen	Optimizing Production under Uncertainty. Generalization of the State-Contingent Approach and Comparison with the EV Model
04/06	Marts 2006	Red. Johannes Christensen	Fremtidens biogasfællesanlæg Nye anlægskoncepter og økonomisk potentiale
03/06	Januar 2006	Jacob Ladenburg	Attitudes towards Wind Power Development in Denmark
02/06	Januar 2006	Johannes Sauer and B. Balint	Romanian Maize – Distorted Prices and Producer Efficiency
01/06	Januar 2006	Johannes Sauer	Economic Theory and Econometric Practice: Parametric Efficiency Analysis
07/05	November 2005	Hans Grinsted Jensen Henrik Zobbe	Domestic Support and the Doha Development Agenda: An exercise in political economy
06/05	August 2005	Jens Kjærsgaard	Incorporating multiple objectives in fisheries management: Experiences and conceptual implications

05/05	Juli 2005	Søren Marcus Pedersen	Potato production in Europe – a gross margin analysis
04/05	Juni 2005	Jens-Martin Bramsen	Kontraktproduktion af slagtekyllinger
03/05	Maj 2005	Henrik Huusom	Administration Costs of Agri-environmental regulations. Empirical Work.
02/05	Februar 2005	Jens Abildtrup, Morten Gylling og Christian Vesterager	Forøgelse af naturværdien på landbrugsejendomme - driftsøkonomiske vurderinger af tiltag
01/05	Februar 2005	Jakob Vesterlund Olsen og Mogens Lund	Effektmåling ved implementering af The Balanced Scorecard på kvægbedrifter